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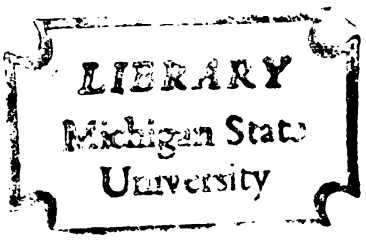

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The Influence of Turkey Skin and Mechanically Deboned Turkey Meat on Functional and Sensory Characteristics of a Smoked Sausage

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Mary Murphy Vallender

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L. E. Dawson

Major professor

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THE INFLUENCE OF TURKEY SKIN AND MECHANICALLY DEBONED TURKEY MEAT ON FUNCTIONAL AND SENSORY CHARACTERISTICS OF A SMOKED SAUSAGE

By

Mary Murphy Vallender

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ABSTRACT

THE INFLUENCE OF TURKEY SKIN AND MECHANICALLY DEBONED TURKEY MEAT ON FUNCTIONAL AND SENSORY CHARACTERISTICS OF A SMOKED SAUSAGE

By

Mary Murphy Vallender

Thirty-six meat blends were formulated using mechanically deboned turkey meat (MDTM) at levels of 25 percent to 75 percent at 10 percent intervals in combination with turkey skin at levels of 0 percent to 25 percent at 5 percent intervals and hand deboned turkey thigh meat to total 100 percent. The raw emulsions formulated from these blends was investigated to ascertain their functional characteristics.

Water binding capacity was adversely affected equally by an increase in skin or MDTM level. Water holding capacity was unaffected by formulation changes, whereas, skin was four times more detrimental to the emulsification capacity than was MDTM.

Regression equations for the functional characteristics were calculated using skin levels and MDTM levels as the independent variables. Taste panel, proximate composition and Kramer Shear Press tests run on four sausage formulations verified the accuracy of these prediction equations.

to Joe, Eric and Marty

my sources of

joy, enthusiasm and peace

ACKNOWLEDGMENTS

"Help me, Cassius, or I sink!"
Shakespeare--Julius Caear Act I Scene 2

This work did not come to fruition without substantial contribution by many people. My statement here cannot express the gratitude I feel, for truly, without their help I would have sunk.

I wish to extend my appreciation to Dr. L. E. Dawson for his guidance, confidence and patience through the long process of completing this project.

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To my husband, Joe, I owe my deepest gratitude, for without his encouragement, enthusiasm, understanding and patience this research would not have been undertaken. I must also thank my sons, Eric and Marty, who through their endless gifts of faith and love keep my endeavors in perspective.

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INTRODUCTION

Sausage popularity by Americans has been well established and these foods now contribute substantially to our total meat protein intake (Kramlich, 1979). Moreover, the growing demand for convenience foods may further boost the popularity of processed meats by over 40 percent within the next decade (Jone, 1973). Simultaneously, the lengthy cattle cycle and high cost of beef production have led to high priced red meat causing a surge of interest in poultry products (Cathcart & Rector, 1978). As a result of these factors, further processed poultry products comprise a growing portion of the total poultry product sales, which increased from 2.3 percent in 1940 to 15.1 percent in 1972 and 20.2 percent in 1978 (Jones, 1973; USDA, 1979). In 1972 turkey products were responsible for the bulk of further processed poultry with 639 million pounds of ready-to-cook turkey meat being further processed. Dawson (1975) reported an increase in the use of turkey in forms other than whole birds from 250 million pounds in 1965 to 900 million pounds in 1974, an average increase of 70 million pounds yearly. Although turkey products still comprise a very large share by volume of the poultry being further processed, with 1211 million pounds (61.1 percent) of ready-to-cook turkey meat being further processed, chicken now holds the largest volume share at 51.4 percent or 1283 million pounds in 1978 (USDA, 1979). While further processing can result in various types of products, rolls, roasts, patties, fried parts, dinners, etc., a

significant amount of further processed poultry results in some type of sausage item, such as bologna, franks, salami or summer sausage.

As the volume of fresh meat passing through a packing plant increases, so does sausage production. These activities are interrelated because the major ingredient used in sausage manufacture is the meat that remains after the most desirable cuts are removed from a carcass. However, because of its relatively boney nature and small muscle size, hand deboning of any poultry muscle except the breast and possibly the thigh muscles, has not been economically feasible. Thus, by-product poultry meat was not available for further processing into sausages. The development of the mechanical deboning machine has changed this situation and now provides a means of removing high quality meat from previously hand deboned racks or under-utilized, difficult to hand bone portions, such as necks and backs. This economical means of salvaging otherwise wasted, high quality protein has made it feasible to increase production of further processed poultry products. In addition, unlike red meat, the skin of poultry is generally considered as part of the meat, further increasing the quantity of meat protein available for use as a sausage ingredient.

It has long been thought that sausage making is an art. In some respects this is true; however, many of the artful practices find their basis in scientific principle. It is only recently, due to the need to employ large-scale mechanical technology for mass production of sausages, that these processes, techniques and, equally important, sausage ingredients have been studied to define the scientific foundation for this art.

There are three types of poultry meat tissues commonly used as ingredients in the production of poultry sausage. These three animal tissues, hand deboned meat (HDM), mechanically deboned meat (MDM), and skin, display dissimilar characteristics. They differ in moisture-protein-fat ratios, amino acid profile and binding properties, as well as in their texture, flavor and appearance. Because of these differences, the effect of their inclusion as a sausage ingredient must be assessed.

This investigation was designed to evaluate what effect the joint inclusion of mechanically deboned turkey meat (MDTM), turkey skin and hand deboned turkey meat (HDTM) would have on the physical properties of an emulsion system. To quantitatively evaluate the functional performance of the emulsion, water binding, water holding and emulsification capacities were determined. Taste panel assessment and shear press determinations were employed to evaluate the meat combinations' performance when used in frankfurter formulations.

REVIEW OF LITERATURE

Hand Deboned Meat

Large muscle groups relatively free from bone structure are most commonly hand deboned. Of these, the lean skeletal muscles are the most desirable ingredient for sausage manufacture. In general, their proteins display greater ability to bind water and emulsify fat than proteins of other origins, two factors of utmost importance in the production of sausages (Kramlich, 1971).

Individual muscles are made up of several muscle bundles; each bundle is composed of numerous fibers and each fiber is composed of many thin, parallel, fibrils, called myofibrils. The myofibrils are held together within a cytoplasmic matrix called the sarcoplasm, which is circumscribed by the sarcolemma, a limiting membrane (Bloom & Fawcett, 1975).

Myofibrils

Myofibrils are the cylindrical, elongated fibrous elements that are responsible for the contractile abilities of muscle (Walls, 1960). These fibrils appear cross striated or banded due to the orderly alignment of successive sarcomeres. The sarcomere is a segment of myofibril which is delimitated by two adjacent Z lines. This narrow dark vertical Z line, or Z disc, results from the intermeshing of filaments from adjoining sarcomers. These segments are comprised of light and dark

bands, and when viewed under polarized light the dark areas are anisotrophic (birefringent) and the light areas, although not totally non-birefringent, are considered isotrophic. They are referred to as A bands and I bands respectively. These areas appear light or dark due to the presence or absence of two types of filaments: thick filaments called myosin and thin filaments called actin. Equal widths of I band exist on either side of the Z line. It is the lightest area and consists of actin filaments exclusively. The A band is the total area which falls between two I bands. In the center of the A band is the dark M line, which bisects a medium dark area called the H band, formed from myosin filaments. The outermost edges of the A band are very dark, being dense with the overlapping of actin from the I band, and myosin from the H band. At this juncture, each thick filament is circumscribed by six thin filaments; each actin is shared by three myosin. Therefore, depending on the location, two myosin filaments can be separated by one or two actin filaments (See Figure 1). It was hypothesized by Hanson & Huxley (1955) that when a muscle contracts the thick and thin filaments slide past each other, while maintaining their initial length, causing a shortening of the sarcomere, thus the myofibril and ultimately the entire muscle (Paul & Palmer, 1972; Cassens, R.G., 1971; Bloom & Fawcett, 1975; Walls, 1960).

Sarcoplasm

The sarcoplasm of a muscle is the contents of the sarcollema; excluding the myofibrils and the cell nuclei, this includes the sarcoplasmic matrix, reticulum and lipid bodies, as well as the sacrosomes and Golgi Apparatus (Bennett, 1960). The sarcosplasmic matrix furnishes

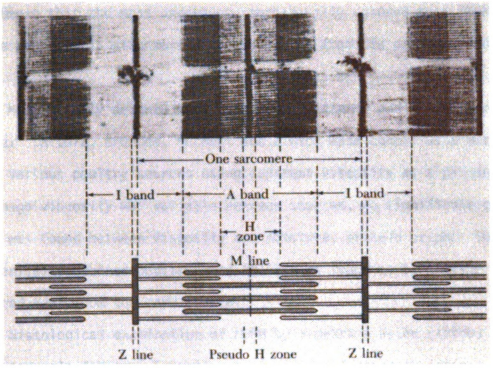


Figure 1. An Electron Micrograph of Muscle Myofibril with an Illustrated Schematic of the Overlap of Filaments that Give Rise to its Band Patterns. (x 23,000)
Taken from Cassens, 1971.

a continous aqueous phase to the filaments which provides for the energy and oxygen needs of the muscle. Within this fluid, many of the soluble muscle proteins, such as myogen and myoglobin, are located.

Mechanically Deboned Turkey Meat

In the mechanical deboning operation, bones with any adhering tissue are initially ground through a bone cutter. The resulting material is then passed through the mechanical deboner where lean is separated from bone by expression through very small holes under pressure, leaving the coarse bone particles behind. Subsequently, because of the severe

treatment that the meat undergoes, mechanically deboned meat (MDM) differs quite markedly in structure and composition from its preprocessed condition.

Mechanically deboned meat has the consistency and appearance of meat paste. In 1972, Grunden, MacNeil and Dimick made comparisons between MDM from various poultry sources using apparent viscosity as a parameter. Although viscosity was variable between sources, no significant correlation was found between viscosity and moisture, protein or pH. The pH of mechanically deboned poultry meat (MDPM) was found to be similar to hand deboned meat from the same source.

Histological examination of MDPM by Vadehra & Baker (1970b) revealed no observable fibers. Schnell, et al. (1974) further investigated the effect that stress during the deboning process had on the ultrastructure of MDPM. They reported an increasing loss in the integrity of the myofibrils as screen size decreased. Breaks were evident at the Z and M bands, effecting the overall length of the fibrils. Upon reduction in size of the myofibrils to small fragments, further shearing produced spherically shaped particles by affecting the fibril width.

Various investigators have evaluated the moisture, fat and protein content of MDPM (Goodwin et al., 1968; Froning, 1970; Froning & Janky, 1971; Grunden, MacNeil and Dimick, 1972; Froning, Satterlee & Johnson, 1973; McMahon & Dawson, 1976b; Janky & Riley, 1977). Froning, in his comprehensive review (1976), summarizes several findings: moisture ranges from 60.1 to 73.7%, fat 12.7 to 27.2% and protein 9.3 to 14.5%. These considerable variations in composition are related to such factors as poultry type, bone-to-meat ratio, bird age, deboner mesh size, and skin content. Generally, however, MDPM was found to have less protein

and more fat than hand deboned poultry meat from a similar source. The primary cause of this decrease in protein content is attributed to the inclusion of fat from skin and/or bone not normally present in hand deboned meat. This fat, in effect, dilutes the percentage of protein present.

In 1971, Satterlee, Froning and Janky evaluated the influence that skin content of chicken carcasses had on the composition of mechanically deboned chicken meat (MDCM). As the skin level on the backs increased, the fat content of the MDCM increased while the percentage moisture and protein decreased. There is a large amount of subcutaneous fat associated with skin which is expressed through the screen with the muscle tissue, causing this apparent increase. In addition, a large amount of lipid is found in bone marrow. During the bone grinding process the marrow contents are exposed and then expressed with the MDM (Moerck & Ball, 1973). Again, the protein content is diluted by fat. Goodwin, et al. (1968) observed that trimming fatty portions from the carcass prior to deboning could reduce slightly the elevation in fat content of MDCM.

The amino acid composition of mechanically deboned turkey meat, (MDTM), was determined by Essary and Ritchey (1968). It was found very similar to the amino acid composition of hand deboned turkey, as well as that of chicken, beef, pork, milk and eggs. They concluded that MDTM would be a satisfactory protein source for use in further processed meat products.

Satterlee, Froning and Janky (1971) investigated MDCM to determine whether skin was being passed through the deboner screen with the product, or whether it was discarded with the ground bone residue. They

found that regardless of the amount of skin introduced into the deboner with the ground carcass, approximately nine to fifteen milligrams collagen, the major protein component in skin, bone and connective tissue, was present in the MDCM. They summarized that the screen of the deboner, while able to pass meat and fat, was holding back the majority of the skin with the bone residue. Probably the tenacious, fibrous nature of the skin prevented enough shearing during deboning to decrease the fiber size sufficient to pass through the small holes of the deboner screen.

Bone

Mechanically deboned meat contins more calcium than hand deboned meat because minute bone particles are passed through the separator with the product. The amount of bone in MDM varies depending on 1) the amount of meat attached to the bone at the time of deboning, 2) the type of equipment used, 3) the degree of crushing the bones undergo prior to separation, 4) the screen size, 5) meat yield, and 6) bone type (Field, 1976b).

Newton (1977) discussed the nutritive value of MDM from the point of view of the calcium it added to the diet. He stated that the average American consumes 800 milligrams less calcium per day than the recommended daily allowance. (Average adult RDA for calcium equals 1 gram, Chaney and Ross, 1971.) A heavy consumption of MDM may add 150-300 milligrams to an individual's daily intake with an increased intake of 10-50 milligrams more likely. He concluded that consumers would benefit by the calcium added to the diet by way of MDM consumption. The USDA select panel (Kolbye and Nelson, 1977), in its final report and recommendations on the "Health and Safety Aspects of the Use of Mechanically

Deboned Meat", also concluded that most people would obtain a slight nutritional benefit from the calcium in MDM, and that this additional calcium intake would not be so great as to pose a health hazard to most individuals.

MDTM was shown to have .13% calcium compared to .02% in hand deboned turkey breast meat by Uebersax, Dawson and Uebersax (1978). Essary (1979) reported values ranging from .11% to .21% calcium in MDTM depending upon the bone types and the sex of the bird. Field, Olson-Womack and Kruggel (1977) reported a range of .76% to 1.04% calcium in mechanically debined beef (MDB) corresponding with a bone content ranging from 2.9% to 4.0%. The actual bone content values were slightly less than the values expected through calculation (percent calcium times a factor of 5, equals percent bone) (Field, et al., 1974). They theorized that some solubilization of bone by the action of water and lactic acid in the meat had occurred.

Of greater concern than amount of bone is the size of the bone particles, due to the problems large particles can cause in mastication and digestion. Indications are that bone particles from hand deboned sources are much larger than those from mechanically deboned sources. Froning (1979) compared the average length and width of bone particles found in MDTM, 410 μ and 233 μ respectively, with those from hand deboned turkey meat, 850 μ and 513 μ respectively. Field, Olson-Womack and Kruggel (1977) separated bone particles from MDB with a diameter averaging 90.3 μ, considerably smaller than that from turkey. However, the screen size that prepared the MDTM was .80 mm while that which prepared the MDB was .46 mm. Reported particle shapes were very similar.

The USDA select panel (Kolbye and Nelson, 1977) concluded that the bone particle size as obtained with current mechanical deboning equipment posed no hazard to health. Although they did recommend that limits on maximum size be included in any proposed regulations.

Effects of MDPM Inclusion in Sausage Formulations

Red meat franks made with the addition of 15% MDTM display only slightly greater cooking losses and lighter color than franks without MDTM. Flavor quality is comparable. Therefore, Froning, et al. (1971), concluded that 15% MDTM could be incorporated in red meat frankfurter formulations without adverse effect.

Investigations by Schnell, et al. (1973) showed that the smaller the screen openings used in MDPM production, the more tender, better flavored and more acceptable the franks made from the product. Frankfurters made from MDPM with a screen size greater than .05 cm, had gritty mouth feel and were less desirable overall.

When MDCM is mixed with ground beef in various combinations up to 50%, acceptable summer sausages with good color, firmness and texture are obtained. At levels exceeding 50% a softer texture results. Summer sausages containing MDCM display better cure color development than those containing hand deboned chicken meat (Dhillon and Maurer, 1975a). Summer sausages containing 50% MDTM or 50% MDCM in combination with 50% beef were evaluated by Dhillon and Maurer (1975b). These sausages were higher in overall shrinkage and displayed an increase in firmness during storage compared to 100% beef sausage. Although the overall acceptability for the sausages was judged excellent by a taste panel, the 100% beef sausage was considered superior.

Meat loaves which contain MDTM show increases in cooked meat yield and loaf volume, as MDTM level increases from 0% to 30%. Cooked slices display increased darkening and reduced binding strength with increased MDTM, while sensory evaluation indicate that substituted loaves are more moist and tender than unsubstituted loaves (Uebersax, Dawson and Uebersax, 1978a).

As protein levels in frankfurters formulated from MDTM increase from 9% to 18%, shear value, emulsion viscosity and yield increase, while taste panel scores for tenderness and juiciness decrease. Franks containing less than 9% protein display unstable emulsions (Baker and Darfler, 1975).

Skin

The major physiological function of skin is to act as a protective encasement for the animal. It is a member of the group of tissues referred to as connective tissues which, in total, provide a supporting framework for the living body. The proteins accountable for this framework are distinctive due to the numerous and variable functions they serve. The primary connective tissue proteins are 1) elastin, 2) collagen, and of substantially lesser import, 3) reticulin. These proteins are extremely fibrous in nature and are responsible for the tensile strength and resilience of the tissue (Bloom and Fawcett, 1975).

Elastin

Elastin is the major protein in elastic fibers and, therefore, also in elastic tissue. The breaking point of these fibers occurs when they are stretched to approximately 150% of their original length. Under expansion conditions less than this, the fibers stretch very easily and

snap back to their original length and shape once the force is removed. Elastin is responsible for the long-term reversible extensibility of arteries, lungs and ligaments (Gosline, 1976), but is only a minor component of skin, tendon, muscle and adipose tissue (Stryer, 1975; Bodwell and McLain, 1971; Seifter and Gallop, 1966).

Elastin and elastic tissue display a yellow appearance and are often referred to as "yellow connective tissue". Although this visual distinction has long been realized, it was believed during the early research of elastin to be a form of collagen. This may have been because these two proteins were found intimately associated within the connective tissue. Ramachandran (1963) reviewed the early studies supporting the hypothesis that elastin was a unique and distinct protein from collagen and this has now been well established.

Under a light microscope elastin fibers appear homogeneous, exhibiting no fibrillar subunits. Instead, they branch and fuse in an irregular manner forming a complex meshwork (Seifter and Gallop, 1966). This meshwork is the result of extensive crosslinking which occurs during polymerization of elastin fibers. In 1963, Thomas, Elsden and Partridge identified two new amino acids which were responsible for the extensive crosslinking, desmosine and isodesmosine. These lysine-derived amino acids, which are probably responsible for the ability of elastin fibers to return to their original shape and size after stretching (Stryer, 1975) are found exclusively in elastic tissue (Seifter and Gallop, 1966). As the animal ages, the amino acid profile of its elastin changes; the lysine content being depleted as it is converted to desmosine and isodesmosine.

Although elastin does contain 1-2% hydroxyproline, it does not contain hydroxylysine. To be considered as part of the collagen family a protein must contain both of these amino acids, which contributes additional evidence that elastin is a unique protein. Interestingly, 95% of the amino acids that make up elastin have non-polar residues: glycine, alanine, proline, isoleucine, leucine and phenylalanine. Of this, one-third of the residues are glycyl, however, unlike collagen they exist in no patterned arrangement (Seifter and Gallop, 1966).

Elastin is a very stable protein being inert to most processes used in food manufacture and preparation. The exception is the ability of certain enzymes, notably ficin, papain and bromelin, to hydrolyze the protein (Bodwell and McLain, 1971). These enzymes are often used in meat tenderizers to reduce the rubbery character of the meat. In sausage manufacture, enzymes are not used; consequently no softening or hydrolyzing of the fibers occur. Therefore, judicious attention must be given during the trimming and chopping procedures to assure that this tenacious tissue is removed and/or finely comminuted. Stringy, tough fibers within the sausage interior may result if adequate care is not taken.

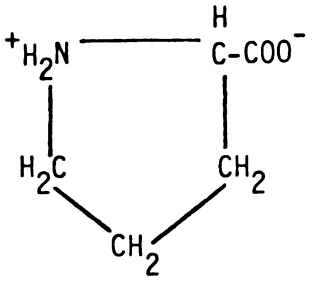
Collagen

Collagen is the most abundant protein found in the mammalian class of animals, representing 20-25% of the total (Seifter and Gallop, 1966). It is found widely distributed throughout the body and is present in nearly all organs. It is of primary importance in skin, bone, tendon and cartilage. Collagen's distinctive property is its ability to form insoluble fibers with inordinately high tensile strength. In addition, its basic structural organization can be modified to serve specific biological

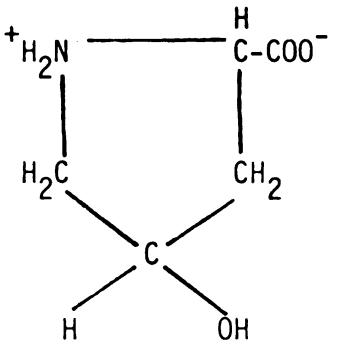
functions. For example, in tissues like tendons which endure considerable stress each fibril has a large diameter which in turn forms a bulky fiber bundle. In contrast, where collagen exists as a light supporting framework, as in cartilage of the ear, it exists as a delicate wickerwork of narrow collagen fibrils (Fietzek and Kuhn, 1976).

The basic structural unit of collagen is tropocollagen which consists of three polypeptide chains of the same size which are coiled into a right-handed helix. Two of the chains are identical, the third is similar. All three chains display nearly a thousand amino acid residues with nearly one-third of those glycine. They also contain two amino acids, hydroxyproline and hydroxylysine, which do not occur in significant quantities in other proteins. Unusually, a regular repeating pattern (glycine-proline-hydroxyproline) occurs, a phenomenon found in few other proteins (Stryer, 1975).

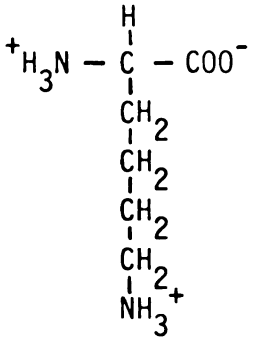
In the synthesis of the polypeptide chains, proline and lysine are incorporated in their unhydroxylated form. It is not until after the chains interact to form the helix that the hydroxylation occurs, aided by enzymes in the presence of ascorbic acid. The result of this activity contributes substantially to the exceptional stability of the triple helix, due to its locking effect (Fietzek and Kuh, 1976). It has been shown that collagen with unhydroxylated proline and lysine residues has an approximately $15^{o}C$ lower denaturation temperature than collagen with hydroxylated proline and lysine residues (Berg and Prockop, 1973). Because only immature, newly synthesized collagen is truly unhydroxylated in its natural state, it is generally agreed that to be considered part of the collagen class of tissues, the amino acid profile must contain both hydroxyproline and hydroxylysine (Harrington and VonHipple, 1961).



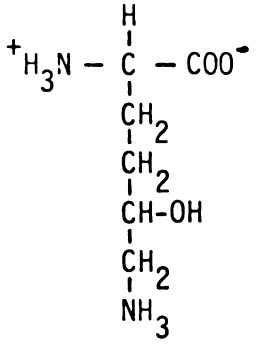
Proline



4-Hydroxyproline



Lysine



5-Hydroxylysine

Hydroxyproline is believed to be exclusively confined to the connective tissues, primarily collagen (Gross and Piez, 1960). Therefore, quantitative assays on this imino acid can also be used to quantify the presence of collagen in tissue. In 1961, J. F. Woessner developed an assay method to determine hydroxyproline content in tissue samples containing only small amounts of the imino acid. This method is far superior to those previously developed and is now commonly used (Satterlee, Froning and Janky, 1971).

Collagen fibers are formed by spontaneous association of tropocollagen fibers into a specific configuration. The fiber's fundamental

structural design is a quarter-staggered array of tropocollagen molecules; adjacent rows of tropocollagen are displaced by one-fourth the length of the basic unit. This arrangement allows the collagen fiber to be several times longer than the tropocollagen molecule while maintaining fiber strength (Stryer, 1975).

Under normal conditions, mature collagen is insoluble and generally unreactive. However, at elevated temperatures, it will shrink to one-third its original length. The specific temperature at which this occurs is contingent upon the amino acid composition and the degree of cross-linking within the fiber. Therefore, shrinkage temperature is species, tissue and age dependent. This shrinkage temperature, T_s, has been reported as low as 40^oC in codskin, to a high of 65^oC in calfskin (Harrington and VonHipple, 1961). It has been suggested that shrinkage results from the initial collapse of the ordered structure of the collagen backbone and a rupturing of many of the molecule binding crosslinks, representing the transition from a crystalline to a non-crystalline state. At temperatures exceeding T_s, the super helix collapses, the chains dissociate and the fibers tend to dissolve resulting in a mixed random coil substance called gelatin (Weiss, 1976). These changes are accompanied by a decrease in viscosity and molecular weight, a negative optical rotation, increased ease of proteolysis and an increased tendency to form gels (Paul, 1972).

Because gelatin is a breakdown product of collagen, by nature it is composed of an assortment of molecular units and cannot be considered as a single compound. Although the molecules are now shorter fragments than those that existed in collagen, they are still fibrous in structure. This long-chain fibrillar structure makes it possible for gelatin to

absorb copious quantities of water, hence its tremendous swelling capabilities.

Many factors effect the degree of swelling that can occur, although fibrillar length is of primary importance. As the alkalinity increases to the maximum of pH 9.0, swelling increases. At pH below 4.0 or above 9.0, gelatin hydrolyzes into small fragments. Salts can also affect the swelling of gelatin. At a pH near the isoelectric point, gelatin swells more in a salt solution than in water. The isoelectric point of a particular gelatin is again a reflection of the degree of hydrolysis which has taken place.

Upon cooling of water swelled gelatin to temperatures below 35^{o}C, viscosity increases until a gel is set. The first step in gel formation is a return of the non-polar regions of the chain high in imino acid residues to the ordered collagen-fold configuration, a partial reversal to the native state. Chains with structured areas coexist with unstructured peptide chains which aggregate and overlap. At the gel point, a continuous network is formed by non-specific bonding between the various chains. The more cross bonds which are formed, the stronger the gel (Paul, 1972).

Effect of Skin Inclusion in Sausage Formulations

The conversion of insoluble collagen to soluble gelatin in the presence of water and heat, and the subsequent formation of a gel upon cooling can cause problems in sausage manufacture. During batter preparation, collagen and muscle proteins seem to perform identically in their ability to coat fat particles. However, during the heating process, the collagen shrinks severely (60-65^{o}C), converts to gelatin

(65°C+) and drains from the fat globule surface. This unbound fat globule then melts and "floats" to the top while the gelatin droplet "sinks" to the bottom, each coalescing with similarly freed fat and gelatin. Upon cooling, the sausage displays a fatcap and a jelly pocket, or in less severe cases fat and jelly pockets appear within the interior of the sausage. Either case is indicative of an unsatisfactory product (Kramlich, Pearson and Tauber, 1973). To minimize this occurrence, it is suggested that a maximum of 25% of high collagen containing meats be utilized in a sausage formulation and a finished sausage should have no more than 25% of its total protein present as collagen (Kramlich, 1971).

The amino acid composition of skin from various poultry sources was determined and assessed by Essary and Young (1977). They concluded that poultry skin is a satisfactory protein source and contributes to the nutritional quality of further processed meat products.

During the investigation of frankfurter peeling ease, it was found that this process was more dependent upon initial smokehouse temperature than upon collagen content in the formulation of beef and pork franks using 10% pork skin to increase collagen content (Saffle, Carpenter and Moore, 1964).

Baker, Darfler and Bourne (1968) evaluated the effect of skin level on the quality of chicken frankfurters when fat, moisture and protein levels were held constant. No differences were detected in quality characteristics until a level of 20% was reached. Then, franks exceeding 20% skin were described as being less juicy, more chewy and more firm.

Nakamura, Sekoguchi and Sato (1975) stated that as chickens aged the amount of crosslinking with collagen molecules increased, resulting

in a greater resistance to heat breakdown. This increased resistance would require a higher processing temperature for skin tenderization.

When Schnell, et al. (1973) added skin to frankfurter formulations, they found that the incorporation of skin increased tenderness perception slightly when judged by a taste panel, but not at all when measured by a shear press. This increased tenderness was attributed to the decrease in protein content caused by the addition of skin rather than the action of the skin proteins. Juiciness was little affected by skin incorporation and only slight differences in flavor and overall acceptability were detected at 30% skin levels as compared to 0%. Viscosity of the raw batter increased with the addition of skin to the formula because the tissue resists fine comminution by the chopper.

Emulsion Systems

An emulsion exists when an immiscible liquid is dispersed, in the form of droplets exceeding 0.1 μ in size, in another liquid. Food emulsions are commonly two phase systems: the dispersed droplet phase being referred to as the discontinuous phase, and the liquid in which the droplets are dispersed being the continuous phase (Paul and Palmer, 1972; Meyer, 1975). These systems consist primarily of two emulsion types: water-in-oil (w/o) and oil-in-water (o/w), the oil refers to any type of lipid whether it be plastic or liquid. These simple emulsion systems are highly unstable, and if allowed to stand, would coalesce into two distinct layers. When stability of the emulsion is necessary, emulsifiers are incorporated to prevent coalescence. These emulsifiers are surface-active agents which decrease the interfacial tension by displaying both hydrophilic and lipophilic properties. If the polar

group of the emulsifier is dominant, it attracts more strongly to water. Thus, water becomes the continuous phase because of its lowered surface tension. If, however, the non-polar groups dominate, the surface tension of the oil would be reduced and oil would, therefore, become the continuous phase (Hansen, 1960; Becker, 1965).

Meat Emulsions

The physical properties and structure of a highly comminuted meat product resemble those of a true emulsion system, thus raw batters are often referred to as emulsions (Hansen, 1960; Swift, Lockett and Fryar, 1961; Carpenter and Saffle, 1964; Meyer, et al., 1964; Borchert, et al., 1967; Townsend, 1968). In the formation of a meat emulsion, the animal fat is the discontinuous phase with the water and salt solution forming the continuous phase. The protein, while acting as the emulsifier, also produces an interwoven, continuous matrix system (Borchert, et al., 1967).

In the process of sausage manufacture, it is imperative that the emulsion remain stable and that there be no separation prior to or during the heating process. Acton and Saffle (1971) determined that the stability of an emulsion is greatly affected by the concentration of proteins in the aqueous phase. Therefore, of primary concern in forming stable emulsions is the solubilization of the proteins which will serve as the emulsifiers. This is accomplished by vigorous chopping of the meat by the knives of a sausage cutter, in the presence of a dilute (2-3%) salt brine (Kramlich, 1971). Following protein extraction, fat and/or fat meats are added during further comminution. This cutting reduces the fat into very small globules while simultaneously encapsulating each

globule with protein, forming a distinct membrane (Hanson, 1960; Swift, Lockett and Fryar, 1961; Helmer and Saffle, 1963). As the fat melts during cooking, it is held within its boundary by this protein matrix. After heating the denatured proteins form dense irregular zones and appear highly disrupted throughout the continuous phase when viewed through an electron microscope (Borchert, et al., 1967).

Swift, Lockett and Fryar (1961) developed a model system to quantify the amount of fat which can be emulsified by various proteins. The method involved the dispersion of protein into a saline suspension, followed by the incorporation of oil at a constant rate to form an oil-in-water type emulsion. Oil addition continued until physical collapse of the emulsion, as indicated by a sudden decrease in viscosity, was observed. This method of quantification was affected by several factors, including the extent to which the meat was comminuted, the proportion of saline phase, the rate of fat addition, speed of mixing, temperature, and concentration of protein. Swift and Sulzbacher (1963) found that pH, salt concentration and amount of added water also cause variations in emulsification capacity (EC) measurement. Modifications of this system have been made by Hegarty, Bratzler and Pearson (1963); Carpenter and Saffle (1964); Borton, Webb and Bratzler (1968); Christian and Saffle (1967); Acton and Saffle (1972); and Kuehler and Stine (1974). Acton and Saffle (1972) pointed out that these numerous modifications make the comparison between various reported EC values difficult to analyze. They summarized the reported EC for beef heart ranging from 22.6 ml oil per 100 mg of protein to 273.2 ml of oil emulsified per 100 mg of protein, obviously a large variation. This range of EC is typical for various proteins reported.

Swift, Lockett and Fryar (1961); Hegarty, Bratzler and Pearson (1963); Pearson, et al., (1965); and Inklaar and Fortuin (1969) all utilized the sudden drop in viscosity which occurs at emulsion collapse as an indicator of emulsion capacity end point. This subjective determination can be highly variable between researchers, particularly with highly viscous emulsions. Webb, et al. (1970) proposed a method to objectively measure EC end point using electrical resistance as measured by an ohm meter. As long as the emulsion remains in the O/W phase, direct electrical current can pass easily through the conductive, continuous phase (water). Upon inversion to a W/O type emulsion the continuous phase (oil) no longer is as highly conductive, and resistance to electrical flow increases dramatically. It is at this point that EC end point is considered attained. However, emulsions of low viscosity tend to exhibit electrophoretic properties which can distort direct electrical current resistance measurement of the end point, while highly viscous emulsions tend to coat the electrodes, increasing resistance. Haq, et al. (1973) suggested the use of alternating current to alleviate some of these problems.

Meat proteins can be divided into three solubility classifications: salt soluble, water soluble and insoluble. The primary salt soluble proteins are the fibrillar proteins, actin and myosin; secondarily are the tropomyosins, troponins and actinins. The water-soluble proteins are generally sarcoplasmic in origin, whereas the insoluble proteins, collagen and elastin, are confined chiefly to the connective tissues.

Swift, Lockett and Fryar (1961) demonstrated that salt soluble proteins were more effective than water soluble proteins in the preparation of an emulsion. Helmer and Saffle (1963) and Trautman (1964) also indicated that the salt soluble proteins were primarily responsible for

emulsion formation. In 1963, Hegerty, et al. reported that water soluble proteins, in the presence of salt, were capable of considerable amounts of emulsion stabilization especially at the pH of fresh meat, 5.6-5.8. Carpenter and Saffle (1965) agreed with these findings and indicated that the emulsifying ability of meat proteins was affected by their molecular shape, as well as the charge on the molecule. However, water soluble and salt soluble proteins reacted differently. By manipulating shape using NaCl and charge by altering the pH, they noted that increased NaCl increased the emulsification capacity in both protein types. However, the emulsification capacity of water soluble proteins grew with lower pH, but it diminished with lower pH in the salt soluble fraction. This supported the work of Swift and Sulzbacher (1963) which showed that peak emulsification capacity was dependent upon both pH and salt concentration for water soluble as well as salt soluble proteins. Generally, however, when pH or salt was increased, emulsification capacity also increased.

Borton, Webb and Bratzler (1968) determined that the prechopping of meat with salt increased its emulsification capacity. They also investigated the EC of lean and fatty sausage meat trim and determined that leaner tissues displayed higher fat EC per unit weight of sample than fattier tissues. However, the proteins from fatty tissues were more efficient emulsifiers, as they displayed higher EC when EC was expressed per unit of protein than did the leaner tissues.

Neelakantan and Froning (1971) found that along with actin and myosin, sarcoplasmic proteins are important to the emulsification process. Their research using turkey muscle protein indicated that water soluble proteins were major contributors to emulsion stability at the pH of post rigor meats.

Emulsifying Characteristics of Poultry Meat

As the use of poultry meat in emulsified sausage products becomes more commonplace, much research has been done to assess its emulsifying characteristics. May and Hudspeth (1966) determined that in various classes of poultry the amount of total protein that was salt soluble was greatest in hen white meat (40.67%), followed by broiler dark meat, turkey dark meat and hen dark meat (16.67%). However, they stated that in all classes of poultry, the dark meat proteins displayed greater emulsification capacity than did the white meat proteins.

Hudspeth and May (1967) noted that the quantity of total protein and of salt soluble protein in light poultry meat exceeds that in dark meat. However, the salt extractable proteins from the dark tissues are more effective emulsifiers than those of the white meat. They concluded that the larger amount of proteins in the white meat were offset by the greater emulsifying capacity of the dark meat proteins, making both muscle types equally valuable to emulsion formation.

Maurer, Baker and Vadehra (1969) suggested that an inverse relationship existed between the concentration of salt soluble proteins and the emulsification ability of poultry parts. They found that those parts which yielded the highest concentration of salt soluble proteins provided the least efficient emulsifiers. Meat from legs and breasts, although lower in salt soluble proteins than thighs, necks and gizzards, were better emulsifiers due to higher protein concentrations. McCready and Cunningham (1971a) demonstrated that although dark meat was lower in total protein and salt soluble protein, its ability to emulsify oil was equal to or greater than that of light meat. They also stated that the pH of dark meat was higher than that of light meat and suggested that

pH was more important to emulsification capacity than was the percentage of salt soluble proteins in the meat tissue.

In 1969, Hudspeth and May investigated the emulsification capacity of the salt soluble proteins from poultry heart, gizzard and skin. They observed that gizzard tissue had the greatest emulsification properties followed by heart, then skin. However, they reported that none of these tissues performed as well as the salt soluble proteins of skeletal muscle.

Investigations by Schnell, et al. (1973) showed that the larger the screen openings used in MDPM manufacture, the less stable the emulsion produced from it. Hand deboned chicken meat emulsions displayed less cook loss than any of the MDCM emulsions.

Maurer and Baker (1966) stated that collagen is detrimental to the emulsification capacity of poultry parts, because it will not dissolve and form stabilizing membranes. Therefore, they assert that collagen content of meat can be used as an estimator of tissue emulsifying efficiency.

Schnell, et al. (1973) reported that skin incorporation into frankfurter formulations caused instability in the emulsion, and a resultant increase in heating losses. This was attributed to a fat content increase and a protein content decrease of the end product as a result of the addition of the skin.

Froning, Satterlee and Johnson (1973) determined that fat content of MDCM increased as the skin content of chicken carcasses prior to deboning increased. This increased fat level contributed to poor emulsification capacity of the tissue. Maurer (1973) concurred with this finding and also determined that mechanically deboned broiler backs and necks emulsified similar volumes of oil as compared to their hand deboned

counterparts. He also investigated the emulsion characteristics of MDP and HDP combinations and concluded that these combinations were functionally very desirable for use in emulsion products.

The source of necks and backs for the production of MCPM has a marked effect on the EC, water holding capacity (WHC), fat and moisture content of the meat. There is a direct correlation between these factors and the fat content of the tissue. It is likely that the level of fat in the meat results from the amount of skin left on the necks and backs during the hand deboning operation and this would vary by source (Orr and Wogar, 1979).

MDTM displays lower emulsification capacity than boneless cow meat on a per gram meat basis, but higher when expressed on a total protein basis. Emulsion stability of red meat franks containing 15% MDTM is only slightly lower than those without MDTM. Stability, with respect to fat release, is identical; however, gel-water release is lower in all red meat franks (Froning, et al., 1971).

Attempts have been made to change and improve MDPM for use in further processing. Froning and Neelanktan (1971) determined that prerigor muscle displayed better emulsifying properties than did postrigor muscle with the prerigor emulsions possessing more uniform round fat globules than the postrigor emulsions. They correlated this improvement to the to the increased pH of muscle in the prerigor state. They suggested that the lowered pH of postrigor meat be adjusted to the pH of prerigor meat to improve emulsion stability and capacity. Froning and Janky (1971) modified MDTM by increasing the pH and/or preblending with salt. Both alterations improved the emulsion characteristics of the meat. Centrifugation to reduce the water and fat content was shown to greatly enhance

the functional characteristics of mechanically deboned fowl meat (Froning and Johnson, 1973), MDCM and MDTM (Dhillon and Maurer, 1975). However, recent work by Maurer (1979) suggests that centrifugal partial dewatering of MDPM does not improve frankfurters made from the product. Improvement was noted by Acton (1973) by extrusion and heat processing to form texturized strands, and McMahon and Dawson (1976) improved the functional characteristics of MDTM by the addition of phosphates.

In frankfurter formulations, MDCM performed less well than hand deboned chicken meat (HDCM) (Froning, 1970). While HDCM produced stable emulstion to a chop temperature of 29.4^{o}C, MDCM emulsions were stable only until 12.8^{o}C was reached. The tensile strength of the finished franks containing MDCM also was significantly reduced when chop temperature exceeded 12.8^{o}C. Photomicrographs revealed that the franks containing MDCM had less protein matrix available for emulsion formation than those containing HDCM. Froning believed that protein denaturation caused by heat and stress during the deboning procedure may have resulted in a loss of protein solubility. Likewise, emulsions prepared from mechanically deboned turkey white meat were stable at 12.8^{o}C but became unstable upon reaching 18.2^{o}C. Photomicrographs taken upon emulsion breakdown show disruption of the protein-fat globule interface as a result of increased chopping time or temperature (Hargus, Froning and Mebus, 1970). Baker, Darfler and Angel (1974) concluded from their research that the end chopping temperature for sausage batters should be kept below 12.8^{o}C to assure stable meat emulsions using MDPM.

Water Binding and Water Holding Characteristics of Poultry Meat

Protein molecules tend to be as hydrophilic as possible. In accomplishing this, the water of meat is present in three phases. A tiny

amount exists as tightly bound water, a layer of water one molecule thick which surrounds the charged and polar groups of the protein. This water is so tightly bound by the proteins that it moves with them in an electric field and no longer exhibits the characteristic freezing point, vapor pressure or solvent ability of normal water (Hazelwood, Nichols and Chamberlain, 1969). This represents 4-5% of the total water in the muscle. The remainder is considered "free" water (Paul, 1972).

Free water is found in two phases. A somewhat larger volume than the bound water yet still small amount, is immobilized as a second layer of molecules over the hydrophilic groups. There is a continuous transition between this immobilized water and the balance of free water. This balance is held in a less organized fashion within spaces found in the network formed by the fibrils, fibers and filaments of the muscle (Bodwell and McLain, 1971; Paul, 1972). The amount of water held depends on the total space available between the filaments. The myofibrils exhibit the greatest amount of water retention due to their three dimensional network of fibrils. Upon homogenization of the meat, as in sausage manufacture, these fibrils are capable of constructing a somewhat open, lacey matrix with large spaces available for water binding. During the heating process the proteins denature as they reach their shrink temperature, T_s. This shrinkage causes free water to be expressed from the interstices as the lacey matrix contracts. In addition, disruption in the continuity of the matrix results providing an escape pathway for liberated water (Paul, 1972).

Many factors affect the proteins' ability to retain water in both the raw and the cooked state. Variations have been observed between meat from different species; pork has a high water binding capacity, followed

closely by beef, then by poultry meat, which has a much lower water binding capacity. The age of the animal is important as is the muscle type. pH also has a profound effect on the proteins' ability to retain water. At the isoelectric point of the protein, there is a balance of positive and negative charges. This attraction pulls the proteins together, minimizing the spaces available for water retention. At pH above or below the isoelectric point, there is a surplus of positive or negative charges respectively. These surplus charges repulse similarly charged proteins resulting in larger interstices where water can collect (Swift and Berman, 1959).

Salt has been shown to affect the water binding capacity of the tissue. Its action results from the chloride ions' considerable attraction by the positive charges and the sodium ions' weak attraction to the negative charges of the protein molecule. This has the overall effect of depressing the isoelectric point consequently increasing the spaces between the filaments at pH above 5.0 (Bodwell and McLain, 1971). Because salt is an essential ingredient in sausage manufacture, and it improves water binding capacity at pH on the alkaline side, phosphates are sometimes incorporated to elevate the normal pH of the meat. Several researchers have noted this synergistic impact of salt and polyphosphates (Bendall, 1954; Swift and Ellis, 1956; Sherman, 1962; Shults and Wierbicki, 1973).

The literature is somewhat conflicting concerning the effect of phosphates and salt on the water holding capacities of MDPM. Vadehra and Baker (1970) stated that the effect of pH on the water holding capacity (WHC) of MDPM is quite different from its effect on native meats. Their study had shown that while WHC of MDPM was improved by the addition

of 1.5% salt, the addition of .5% Kena (a food grade mixture of phosphates) had no effect. Froning and Janky (1971) reported that both increased salt and increased pH improved emulsion stability and decreased cooking losses. Whereas, McMahon and Dawson (1976) reported that .5% phosphate had a greater effect than salt or salt plus phosphate preblending on the water binding and water holding abilities of MDTM.

MATERIALS AND METHODS

Source and Processing of Meat

Turkey meat was obtained from a commercial processing plant located in Athens, Michigan (Notawa Gardens). There, meat and skin were placed in polyethylene bags and packed into insulated boxes for transport back to the laboratory. It was then ground or rendered, if necessary, and packaged into experimental units, frozen and maintained at -18^{o}C.

A Beehive Model AU968MF mechanical deboner with a mesh setting of 1mm was used to process the mechanically deboned turkey meat (MDTM). Samples taken from the deboner for use in collagen determinations were described as follows; the term "product" denoted the deible meat portion which passed through the mesh openings; "residue" denoted the inedible portion passed out of the deboning head, consisting primarily of bone and connective tissue. Samples obtained from turkey "racks" were the products and residues obtained when turkey carcasses, hand deboned of their breast muscles, wings and legs were passed through the mechanical deboner. Samples from turkey "backs" were the products and residues obtained when the turkey carcass, minus its breast muscle and breast bones, legs and wings were passed through the mechanical deboner. MDTM samples were obtained from carcasses which either had all visible skin removed or which retained the skin present after the hand deboning operation. These are designated as "stripped" and "unstripped" samples respectively. MDTM used in functional investigations and in product

manufacture is the edible portion or "product", from unstripped racks and will be referred to simply as MDTM.

All hand deboned turkey meat (HDTM) used in this investigation came from turkey thighs. It was ground twice in a Hobart food grinder, first with a 10mm hole plate then with a 5mm hold plate. This was done within twenty-four hours of sample collection.

The turkey skin consisted of those portions that were stripped off of the carcass during the hand deboning operation, primarily from the breast, thigh and drumstick areas. In the laboratory the tissues were cut into strips, placed on aluminum trays, frozen and then quickly passed through a Hobart food grinder fitted with a 10mm hole plate. They were frozen and passed again through a 3mm hole plate.

Turkey fat used in the manufacture of sausage was obtained by rendering the subcutaneous fat associated with skin. Prior to rendering, the skin was ground in the same manner as described above. The ground tissue was then slowly heated over low heat for five to six hours. The solids were removed and the liquid was strained through cheesecloth. Three hundred milliliters of distilled water was stirred into the rendered liquid which was then held at $4^{o}C$ overnight. The following day the fat phase was removed and the water phase, which had been gelled by the solubilized gelatin, was discarded. The fat was then reheated over low heat and the solids were periodically skimmed off the surface. After five to six hours, the fat was strained through cheesecloth into glass containers, covered with polyethylene film and frozen at $-18^{o}C$ until use. Analysis of the fat indicated an essentially water and solids free material.

Chemical and Physical Analyses

Moisture

The A.O.A.C. (1975) procedure for moisture determination was used throughout this investigation. One to four grams of sample were weighed into aluminum moisture pans and dried in an air convection oven at 100°C for eighteen hours. After cooling in a dessicator, the samples were reweighed. Results are expressed as percent moisture lost due to drying and were calculated using the following equations:

$$\text{percent total solids} = \frac{\text{dried sample weight}}{\text{fresh sample weight}} \times 100$$

$$\text{percent total moisture} = 100\% = \%\ \text{total solids}$$

Fat

Fat quantification was achieved by ether extraction using a Goldfisch apparatus, following A.O.A.C. (1975) approved methods. The solids remaining after moisture determinations had been made, were subjected to continous extraction with anhydrous diethyl ether for three and one-half hours. After the ether had evaporated and the extracted material dried for one hour in a convection over at 100°C, the weight of the lipid fraction was determined. Results are expressed as percent fat present in the fresh sample and were calculated using the following equation:

$$\text{percent fat} = \frac{\text{ether extract weight}}{\text{fresh sample weight}} \times 100$$

Protein

The A.O.A.C. (1975) method for quantifying protein was followed using a semi-micro Kjeldahl procedure. Triplicate 0.5 g meat samples were digested by 1 g sodium sulfate, 7 ml concentrated sulfuric acid and 1 ml of 10%, (w/v), copper sulfate solution, with heat, to a pale green endpoint. The digested sample was neutralized with 35 ml of 50% sodium hydroxide and distilled into 20 ml 2% boric acid. The distillate was then titrated to a colorless endpoint using standardized .1N sulfuric acid with brom cresol green as an indicator. Percent protein was calculated using the following equation:

$$\% \text{ protein} = \frac{(\text{N of } H_2SO_4)\ (\text{net ml } H_2SO_4)\ (.014)\ (6.25)}{\text{fresh sample weight in grams}} \times 100$$

Hydroxyproline (Collagen) Analyses

Hydrozyproline determinations were made on the eleven treatment groups presented in Table 1.

Table 1. Treatment Groups Evaluated for Hydroxyproline Content

TREATMENT GROUP	ABBREVIATION
residue from stripped back	RSB
product from stripped back	PSB
residue from unstripped back	RUB
product from unstripped back	PUB
residue from stripped rack	RSR
product from stripped rack	PSR
residue from unstripped rack	RUR
product from unstripped rack	PUR

Hydroxyproline (Hyp) content was determined following the procedure of Woessner (1961). A desicatted, defatted sample of .05 g was hydrolyzed in 5 ml of 6.6N HCl at 130°C for six hours. The hydrozylate was neutralized with 2.5N NaOH using methyl red as the indicator. Samples from "products" were then brought to 250 ml with distilled water and those from "residues" brought to 500 ml, this insured that 1 ml of diluted sample would contain at least 1 µg and not more than 5 µg Hyp. These solutions were determined by preliminary investigations and were necessitated by the limitations of the method.

Three prepared standards were run with each analysis for the construction of a standard curve; 0 µg Hyp, 2.5 µg Hyp, and 5.0 µg Hyp.

Analysis of one milliliter of the standard solution or hydrolyzed sample were run in duplicate tubes. Oxidation was initiated by the addition of 1 ml fresh .05M Chloramine T (sodium p-toluene-sulfonchloramide) solution. The tubes were vortexed and allowed to stand for twenty minutes at room temperature. One milliliter of 3.15M percholoric acid (27.0 ml of 70% percholoric acid to 100 ml with distilled water) was then added to each tube, following the same sequence, to terminate oxidation. The contents were again vortexed and allowed to stand five minutes. In the same order, 1 ml freshly prepared 20% p-dimethylaminobenzaldehyde was added to each tube and shaken until no schleiren was evident. The color was developed by placing the tubes in a 60°C water bath for twenty minutes, followed by five minutes in a cool tap water bath. The absorbency of the solution was read spectrophotometrically at 557 mu within one hour.

A stock solution of Hyp for the standards was prepared by dissolving 25 mg of vacuum dried L-Hyp in 250 ml of .001N HCl. Standards

were prepared daily by diluting the stock with distilled water to obtain the desired concentration.

A .05M chloramine T solution was prepared daily by dissolving 1.41 g chloramine T in 20 ml water, then adding 30 ml Piersolve, (ethylene glycol monomethyl ether, Pierce, Inc., Rockford, Illinois) and 50 ml buffer. The solution was held in a glass stoppered bottle.

The buffer was prepared by combining 50 g citric acid monohydrate, 12 ml glacial acetic acid, 120 g sodium acetate trihydrate and 34 g sodium hydroxide with enough distilled water to make one liter. Adjustment to pH 6.0 was made with dilute NaOH. The buffer was then stored in a glass bottle under toluene.

A 20% p-dimethylaminobenzaldehyde solution was prepared just prior to use by adding Piersolve to 10 g of the powder to give a final volume of 50 ml. To aid in solubilization, this solution was warmed in a 60^{o}C water bath.

Because hydroxyproline composes 13.2% of collagen (Bower et al., 1967), multiplication of the hydroxyproline content of the sample by a factor of 7.57, yielded the collagen content of the dried defatted sample.

Functional Analyses of Meat and Skin Systems

Functional properties: water binding, water holding and emulsification capacities of thirty-six meat comginations formulated with various levels of HDTM, MDTM and turkey skin were evaluated. The combinations investigated are presented in Table 2.

Table 2. Meat Combinations Investigated for Their Functional Properties

HDTM %	MDTM %	SKIN %	CALCULATED PERCENT PROTEIN IN SAMPLE
0	75	25	15.1
5	75	20	15.4
10	75	15	15.7
15	75	10	16.0
20	75	5	16.2
25	75	0	16.5
10	65	25	15.4
15	65	20	15.7
20	65	15	16.0
25	65	10	16.3
30	65	5	16.5
35	65	0	16.8
20	55	25	15.7
25	55	20	16.0
30	55	15	16.3
35	55	10	16.6
40	55	5	16.8
45	55	0	17.1
30	45	25	16.0
35	45	20	16.3
40	45	15	16.6
45	45	10	16.9
50	45	5	17.2
55	45	0	17.5
40	35	25	16.3
45	35	20	16.6
50	35	15	16.9
55	35	10	17.2
60	35	5	17.5
65	35	0	17.8
50	25	25	16.7
55	25	20	16.9
60	25	15	17.2
65	25	10	17.5
70	25	5	17.8
75	25	0	18.1

Water Binding Capacity

The water binding capacity (WBC) of the meat was determined by a modification of the method of Wierbicki et al. (1962) by Shults et al. (1972) and expressed as the percent increase in weight due to absorbed water (swell), as well as milliliters water bound per gram protein. Appropriate amounts of HDTM, MDTM and turkey skin were combined to a total weight of fifty grams. The meat was then placed in a pint jar, mixed with 100 g distilled water and blended for two minutes in an Osterizer at 10,000 RPM. The slurry was transferred to a 250 ml centrifuge tube and spun for twenty minutes at 2500 RPM. The contents of the tube were then decanted through a strainer into a funnel which lead to a graduated cylinder. After a one hour settling period, the amount of supernatant was measured. The calculations used are as follows:

$$\text{percent swell} = \frac{(\text{wt of slurry} - \text{wt of meat}) - \text{ml supernatant}}{50 \text{ grams}} \times 100$$

$$\frac{\text{ml water bound}}{\text{gram protein}} = \frac{100 \text{ ml} - \text{ml supernatant}}{\text{grams protein in 50 gram sample}}$$

Water Holding Capacity

The water holding capacity (WHC) of the meat was determined by a modification of the method of Wierbicki et al. (1957b), and expressed as the percent moisture lost per gram of meat under heated conditions, as well as percent moisture lost per gram protein due to heating.

Appropriate amounts of HDTM, MDTM and turkey skin were combined to a total weight of 50 g. The meat was placed in a pint jar with 35 ml distilled water and blended for two minutes using an Osterizer blender at 10,000 RPM. One gram of the slurry was removed for moisture determination. Fifty grams of slurry were placed into a 250 ml centrifuge

tube and sealed tightly. The tubes were spun at 1000 RPM for thirty seconds to insure uniform packing of the meat within all tubes. They were then heated for thirty minutes in a 70°C water bath. All tubes were weighed before and after heating to assure that no moisture was lost or gained during the heating procedure. The samples were cooled in running water for thirty minutes, then centrifuged at 2000 RPM for ten minutes. The supernatant was then decanted through a strainer into a funnel placed over a graduated cylinder. After a half hour settling period, the amount of supernatant, excluding the fat layer, was measured. The fat was aspirated off and a one ml sample of the supernatant was extracted and dried to assess the moisture content. The amount of moisture lost during heating was calculated as follows:

$$\text{percent water lost} = \frac{\text{ml supernatant X (\% } H_2O \text{ in supernatant)}}{\text{\% } H_2O \text{) in sample X grams sample}} \text{ X } 100$$

$$\frac{\text{\% water lost}}{\text{gram protein}} = \frac{\text{\% water lost per gram meat}}{\text{grams protein in fifty ml of slurry}}$$

Emulsification Capacity

The emulsification capacity (EC) of the meat blends was determined by the method of Swift et al. (1961) using the modification of Webb et al. (1970) and is expressed as milliliters oil emulsified per gram of meat and as milliliters oil emulsified per gram of protein.

Appropriate amounts of HDTM, MDTM and turkey skin were combined to a total of twenty grams. The meat was blended with 200 ml cold 1M NaCl in a Waring blender at 10,000 RPM for five minutes. The temperature of the slurry was determined and any sample that fell out of a range of 25°C - 30°C was deleted. Ten grams of the slurry were then placed into

a 600 ml beaker and 20 ml cold 1M NaCl were added. The weight of the beaker and contents were taken and recorded. A triple bladed, single rod propeller powered by a "Lightin Mixer", model L was placed in the beaker. The mixture was blended for thirty seconds at 7000 RPM, and then the addition of corn oil (Mazola) began at the rate of 1 ml per second. The delivery tube was positioned so that the oil was deposited as close to the vortex as possible insuring complete incorporation into the emulsion. See Figure 2 for the setup of the emulsion apparatus. Oil delivery and emulsion formation continued until electrical resistance through the emulsion reached infinity, as measured by an ohm meter. Oil flow was halted immediately, and the beaker and its contents were weighed. See Figure 3 for emulsion formation and measurement display. The weight of the oil added was determined by difference and converted to milliliters by a factor of .9185. The emulsification capacity of a 20 ml NaCl blank was also determined, and this value was subtracted from all experimental measurements to obtain the total milliliters of oil emulsified by the meat. Calculations were as follows:

$$\text{Milliliters oil} = \frac{\text{grams oil}}{.9185}$$

$$\frac{EC}{\text{gram meat}} = \frac{\text{ml oil emulsified by sample - ml oil emulsified by blank}}{\left(\frac{A \quad X \quad B}{C}\right)}$$

$$\frac{EC}{\text{gram protein}} = \frac{\left[\frac{\text{ml oil emulsified by meat}}{\left(\frac{A \quad X \quad B}{C}\right)}\right]}{\text{\% protein in meat}}$$

When A = grams of meat (20)

B = grams of slurry evaluated (10)

C = grams of meat + grams of NaCl (228)

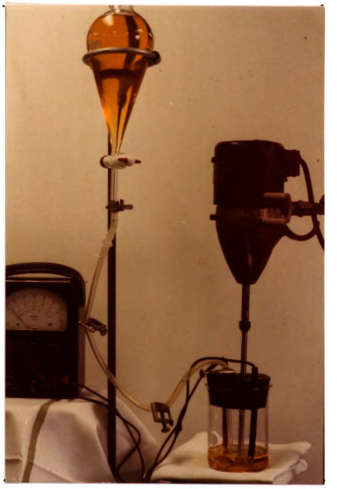


Figure 2. Setup of Emulsion Formation Apparatus Showing from Left to Right, Ohm Meter, Oil Reservoir and Delivery Tubing, "Lightin Mixer" and Beaker.

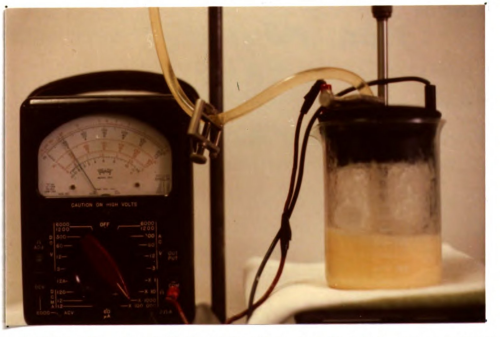


Figure 3. Example of Emulsion Formation and Ohm Meter Measurement.

Sausage Manufacture and Evaluation

Sausage Manufacture

The four treatments to be evaluated were selected because of their water binding and emulsification capacities as predicted by regression equations calculated from the data obtained from analysis of the functional characteristics of the system (see the appropriate discussion). The meat combinations presented in Table 3 were used for sausage manufacture.

Table 3. Meat Combinations Evaluated by Sausage Manufacture

TREATMENT	MDTM %	HDTM %	SKIN %
1	28.5	61.0	10.5
2	17.0	61-0	22.0
3	52.0	34.5	13.5
4	64.5	34.0	1.5

One batch of each of the four treatments was prepared on two successive days. All treatments were held until the third day so that all samples could be cooked and smoked together.

Fresh meat and skin were obtained and ground as discussed earlier. Fat was rendered from fresh skin. In order to prepare batches with similar compositions, triplicate samples of the raw materials were analyzed for fat and moisture. Protein content was calculated by difference, allowing one percent for ash. Using these values, the amount of fat and ice to be added was calculated using a modification of the method of Baker, Darfler and Bourne (1968) as follows:

1. $$\frac{HD_p \text{ X HDTM}}{100} + \frac{MD_p \text{ X wt MDTM}}{100} + \frac{S_p \text{ X wt skin}}{100} = T_p$$

2. $$\frac{T_p}{B_p} \text{ X } 100 = \text{TBW}$$

3. $$\frac{B_f \text{ X TBW}}{100} - \frac{HD_f \text{ X wt HDTM}}{100} - \frac{MD_f \text{ X wt MDTM}}{100} - \frac{S_f \text{ X wt skin}}{100} = \text{weight of fat to add}$$

4. $$\frac{B_w \text{ X TBW}}{100} + \frac{\text{TBW X SS}}{100} - \frac{HD_w \text{ X wt HDTM}}{100} - \frac{MD_w \text{ X wt MDTM}}{100} - \frac{S_w \text{ X wt skin}}{100} = \text{weight of water to add (in form of ice)}$$

When:
- HD_p = % protein in HDTM
- MD_p = % protein in MDTM
- S_p = % protein in skin
- B_p = % protein in finished batch
- T_p = total amount of protein in finished batch
- HD_f = % fat in HDTM
- MD_f = % fat in MDTM
- S_f = % fat in skin
- B_f = % fat in finished batch
- HD_w = % water in HDTM
- MD_w = % water in MDTM
- S_w = % water in skin
- B_w = % water in finished batch
- TBW = total batch weight
- SS = % allowance for smokehouse shrink

All batches were calculated for a finished composition of 12% protein and 25% fat. A smokehouse shrink of 13% was allowed, as this was the typical amount incurred by emulsion type sausages cooked in the Michigan State University Meat Laboratory smokehouse. A commercial seasoning and cure mix was used, (All Meat Weiner or Bologna Seasoning and Cure Twinpak, B. Heller and Co., Bedford Park, Illinois). The seasoning consisted of salt (55%), corn syrup solids (35.4%), mustard (16.7%), spice extractives on a dextrose carrier and sodium erythorbate (0.52%) with not more than 2% tricalcium phosphate and tetrasodium pyrophosphate added as anti-caking agents. It was incorporated at the level of 27.21 g per pound of meat.

The cure was composed of salt and sodium nitrite (6.25%) with not more than 2% propylene glycol used as an anti-caking agent. It was incorporated at the level of 11.34 g cure per ten pounds of meat. The resultant recipes are given in Table 4.

Table 4. Ingredients Used in Sausage Manufacture

Tmt	MDTM lbs.	HDTM lbs.	SKIN lbs.	FAT lbs.	ICE lbs.	SEASONING grams	CURE grams
1	2.85	6.10	1.05	2.24	3.86	333.12	13.88
2	1.70	6.10	2.20	1.85	3.24	322.50	13.43
3	5.20	3.45	1.35	1.78	2.79	320.60	13.34
4	6.45	3.40	1.50	1.97	3.07	362.51	15.10

Meat mixtures were prepared in eleven to fourteen pound batches, following customary processing procedures. Skin, HDTM and seasoning were mixed together in Hobart K5A mixers for two minutes to initiate extraction of the salt soluble proteins. The MDTM was then added and mixed

for one minute, followed by addition of the cure and one minute additional mixing. The meat was transferred to a Hobart Food Cutter, Model 84181D and the ice was added. Chopping commenced for ten minutes or until a temperature of 40°F was reached, whichever came first. The fat was then added and chopping resumed for six minutes or until 50°F was reached, whichever came first. Throughout the chopping cycle, the cutter was stopped periodically at predetermined intervals to scrape the cutter bowl, thus insuring equal distribution of ingredients. After being stuffed into #34 collagen casings (Brechteen Co., Mt. Clemens, Michigan) and tied at approximately 25 cm lengths, the sausage was suspended on smoke sticks and wrapped in a plastic film to decrease the amount of dehydration that might occur. It was then held at 4.5°C until smoking.

The sausages were cooked in a smokehouse according to the schedule presented in Table 5. Cooking was terminated when an internal temperature of 156°F (68.9°C) was reached. The sausages were showered with cold water for twenty-five minutes before removal from the smokehouse. Afterwards, they were placed in large plastic bags and held to age at 4.5°C for eleven days.

Table 5. Smokehouse Cook Procedure

Duration Minutes	Dry Bulb °F (°C)	Wet Bulb °F (°C)	Relative Humidity
60	135 (57.2)	92 (33.3)	27%
40	145 (62.8)	115 (46.1)	40%
60	155 (68.3)	135 (57.2)	55%
20	165 (73.9)	155 (68.3)	77%

Texture Evaluation

Shear strength was determined using as Allo-Kramer Shear Press, Model T2100, fitted with a standard shear cell. Three determinations of both hot and cold samples were made on each treatment.

Samples to be sheared hot, were heated in a simmering water bath for five minutes. The sausage was then cut into 65 mm lengths, weighed and placed side by side into the cell perpendicular to the slots. A 3000 lb ring was used with a range setting of 10 and a downward stroke of 30 seconds. Pounds of force per gram of sample required to shear were calculated as follows:

$$\frac{\text{Pounds of force}}{\text{gram sample}} = \frac{\text{lb. ring} \times \frac{\text{range}}{100} \times \frac{\text{peak height}}{100}}{\text{Sample weight in grams}}$$

Sensory Evaluation

Taste panelists were drawn from faculty, staff and students in the Department of Food Science and Human Nutrition. Hot sausage samples were assigned three digit code numbers and presented to each panelist with the casing slit for easy removal. Psychological biases were minimized in accordance with Amerine, Pangborn and Roessler (1965).

Each panelist rated four samples of differing treatments on five parameters: greasiness, moistness, elasticity, cohesiveness and uniformity. A nonnumeric, continuum style scale was used to minimize bias. A scale with a value range of .5 (best, most) to 7.5 (worst, least) was superimposed on each panelists' reply sheet during statistical analysis.

In addition each panelist was asked to rank the four samples on the basis of juiciness. Juiciness was defined, by way of cover instructions, as "the degree of liquid released upon chewing". The most juicy sample

was ranked number one, while the least juicy sample was ranked number four. See Appendix I for taste panel instruction sheet and reply forms.

RESULTS AND DISCUSSION

Collagen Determinations in Product and Residues Following Mechanical Deboning of Turkey Carcasses

Residue and product from turkey racks and backs, some stripped of visible skin and some not stripped, were analyzed to assess whether the skin was expressed through the mesh screen of the mechanical deboner with the edible product, or whether it was passed through the deboner head with the residue portion. Because collagen is the primary protein of skin and hydroxyproline is confined almost exclusively to the structure of collagen and elastin, quantification of hydroxyproline followed by appropriate mathematical conversions was used to determine the quantity of connective tissue in each treatment group

The composition of the various products and residues analyzed is summarized in Table 6. Results of the collagen determinations are graphically illustrated in Figure 4.

The moisture (68.84%) and fat (13.42%) content of the product from unstripped racks (PUR), which would be equivalent to commercial MDTM, fell well within the ranges reported by Dawson (1975) and in Froning's summary of values (1976).

Difficulties were encountered as samples of raw product and residue were taken for the hydroxyproline analyses. Although the residue had been well ground by the mechanical deboner and was reground in the laboratory, pieces of bone and fibrous material, primarily stringy

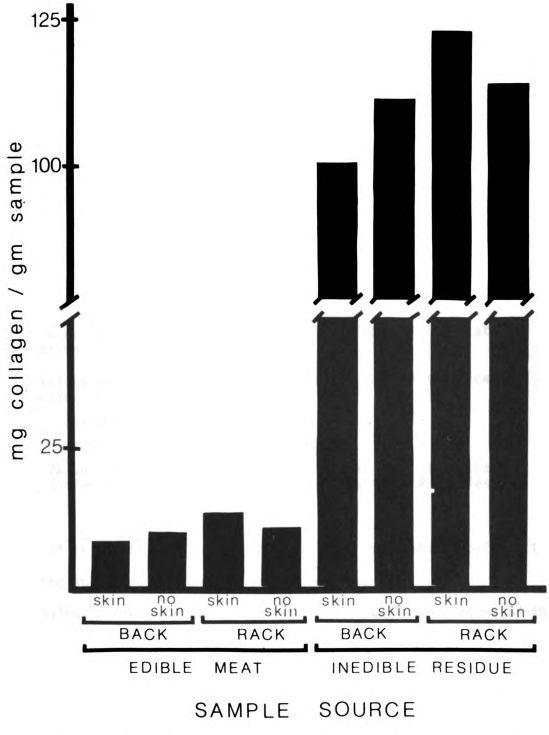


Figure 4. Amount of Collagen in the Residue and Product from Skin Containing and Skinless Turkey Racks and Backs after Processing through a Mechanical Deboner.

Table 6. Proximate Composition of Mechanically Deboned Turkey Products and Residues.

Source of Variation	Moisture[1]	Fat[1]	Collagen[2]
	percent		mg/gram sample
RSB	51.03 ± 2.67	10.64 ± .15	111.77[b] ± 8.65
PSB	65.07 ± 1.10	20.32 ± 1.58	10.36[d] ± 2.55
RUB	51.97 ± 2.77	14.81 ± .29	100.45[c] ± 7.05
PUB	60.33 ± .63	25.50 ± 1.00	8.70[d] ± .63
RS<u>R</u>	56.18 ± 3.90	7.95 ± .22	114.31[b] ± 9.21
PS<u>R</u>	73.03 ± .17	12.06 ± .11	10.80[d] ± 2.23
RU<u>R</u>	53.92 ± 1.83	7.28 ± .19	123.76[a] ± 7.30
PU<u>R</u>	68.84 ± .26	13.42 ± .27	13.68[d] ± 1.55

[1]Values are the means and standard deviations of duplicate replications on duplicate samples.

[2]Values are the means and standard deviations of triplicate replications on duplicate samples

R - residue S - stripped B - back

P - product U - unstripped <u>R</u> - rack

Note: Values that have the same superscript are not significantly different, as determined by Duncan's Multiple Range Test.

pieces of skin, still existed. This made uniform sampling difficult resulting in the large standard deviations reported.

Obvious differences were seen between the collagen content of the residue and product portions, with the bulk of the collagenous material being passed through the mechanical deboner with the residue. No significant differences were found in the amount of collagen present in the edible meat regardless of whether or not the skin was stripped prior to deboning. This small amount of collagen, 8-14 mg per gram meat, agrees

with the published results of Satterlee, Froning and Janky (1971) who reported values of 10-15 mg collagen per gram meat in samples with initial skin levels between 0 and 45 percent.

There was a significant difference in the amount of collagen present in the residue samples from the stripped and unstripped carcasses. As expected, the turkey racks which retained their skin after the hand deboning operation showed significantly more collagen in the mechanically deboned residue (RSR) than did those samples from which the skin was removed (RUR). However, the collagen content from the residue of the stripped backs (RSB) was higher than the collagen content from the residue of the unstripped backs (RUB). This seemingly contradictory result may be attributed to the significantly higher fat level in the unstripped sample as compared to the residue from the stripped sample. This increased fat content dilutes the amount of collagen present, giving a result reported as mg collagen per gram meat, a lower value. From these data it was concluded that very little collagen was being expressed with the MDTM, consequently its effect in subsequent analyses should be negligible.

Evaluation of Emulsion Systems

To evaluate what effect the combining of turkey skin, MDTM and HDTM would have on the physical properties of an emulsion system, water binding, water holding and emulsification capacities were determined. These are properties which can quantitatively evaluate functional systems vital in assuring proper sausage manufacturing.

Water Binding Capacity

Mean values of the water binding capacity (WBC) for the meat combinations are summarized in Tables 7 and 8. Table 7 shows the percentage swell or the percent increase in volume of the meat due to bound water (on a meat basis), while Table 8 reports the milliliters of water bound per gram of protein (protein basis). Regardless of the manner in which the results are expressed, water binding is detrimentally affected by the inclusion of either skin or MDTM in the formulation (See Table 9). Interactions between skin and MDTM are not significant.

Both skin and MDTM have higher fat levels associated with them than does HDTM. The fat does not contribute to the protein function, rather it inflates the detrimental impact the use of these meats display. Because protein efficiency is of the foremost interest, results are expressed in relation to the amount of protein (protein basis) in the sample rather than by the amount of meat in the sample (meat basis). This is a more sensitive indicator of the system's functioning. Also, in sausage manufacture the fat and protein levels are standardized by the formulation, this negates the influence which fat content variability has on the functional properties.

A regression equation was calculated from the data which was evaluated on protein basis. The resultant equation was:

$$WBC = 3.998 - .0153X_1 - .0151X_2$$

X_1 = skin level in percent

X_2 = MDTM level in percent

This equation was judged to accurately describe the formulation effects by an analysis of variance for the overall regression (Table 10). Figure 5 is a graphic illustration of the equation.

Table 7. Mean Percentage Volume Increase Due to Bound Water of Meat Formulations Containing HDTM, MDTM and Turkey Skin.

MDTM LEVELS (percent)	SKIN LEVELS (percent) 0	5	10	15	20	25	Marginals
75	49.67	43.00	49.00	42.33	35.00	37.33	42.72
65	51.33	50.67	46.33	47.33	40.67	36.33	45.44
55	57.33	48.00	49.33	51.67	46.00	40.67	48.83
45	53.33	55.67	60.00	47.33	48.33	44.33	51.50
35	58.00	60.00	60.67	57.00	58.33	54.00	58.00
25	59.67	62.33	61.33	58.33	57.33	56.33	59.22
Marginals	54.89	53.28	54.44	50.67	47.61	44.83	

Mean values of three replications.

Table 8. Mean Milliliters of Water Bound per Gram of Protein in Meat Combinations Containing HDTM, MDTM and Turkey Skin

MDTM LEVELS (percent)	SKIN LEVELS (percent) 0	5	10	15	20	25	Marginals
75	3.01	2.65	3.06	2.69	2.27	2.47	2.69
65	3.06	3.07	2.84	2.95	2.59	2.41	2.82
55	3.35	2.86	2.98	3.17	2.87	2.59	2.97
45	3.05	3.24	3.55	2.85	2.96	2.77	3.07
35	3.34	3.43	3.53	3.37	3.21	3.31	3.36
25	3.29	3.50	3.51	3.39	3.39	3.37	3.41
Marginals	3.18	3.12	3.24	3.07	2.88	2.82	

Mean values of three replications.

Table 9. Analysis of Variance of the Water Binding Capacity of Meat Formulations Containing HDTM, MDTM and Turkey Skin

Source of Variation	Degrees of Freedom	F Statistic	Significance
Meat Basis			
Main Effects			
Skin	5	18.25	.0005
MDTM	5	49.31	.0005
Interaction			
Skin X MDTM	25	1.79	.029
Protein Basis			
Main Effects			
Skin	5	8.44	.0005
MDTM	5	24.34	.0005
Interaction			
Skin X MDTM	25	1.71	.040

Table 10. Analysis of Variance for the Overall Regression of the Water Binding Capacity (WBC) of Meat Formulations Containing HDTM, MDTM and Turkey Skin

	Degrees of Freedom	F Statistic	Significance	Correlation Coefficient
Regression	2	60.497	.0005	.7317

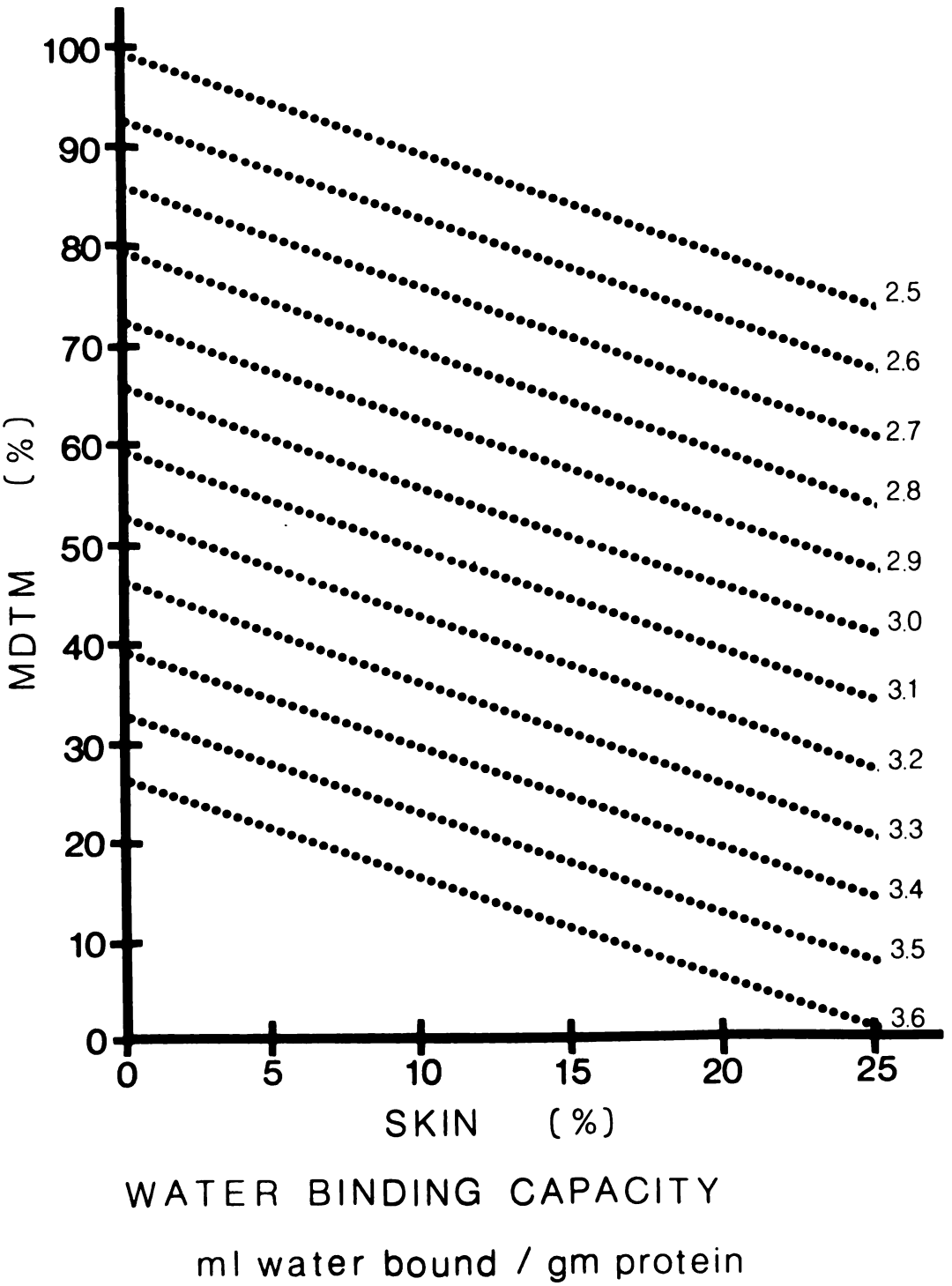


Figure 5. Water Binding Capacity of HDTM, MDTM and Turkey Skin Combinations as Predicted by Calculated Regression Equation, ($WBC = 3.998 - .0153X_1 - .015X_2$).

Both skin and MDTM inclusion were equally detrimental to the WBC of the formulation. It is likely that the decrease in fibril length and width of MDTM prevents the formation of large interstices with which to bind water. Similarly, the compact pleated sheet arrangement of the collagen fibers cause difficulty in formation of an open matrix. In both cases, the WBC was less than that for HDTM. As the amount of skin or the amount of MDTM in the formulation increased, the WBC decreased.

The regression equation can be used to predict the relative WBC of a formulation combining HDTM, MDTM and turkey skin. Any meat combination falling along the same regression line should give equivalent WBC. Combinations falling along two different lines should give different WBC.

Water Holding Capacity

Mean values of the water holding (WHC) for the meat combinations are summarized in Tables 11 and 12. Table 11 reports the percent water lost from the total meat sample (meat basis), whereas Table 12 shows the results as percent water lost per gram protein (protein basis). These results fall within a similar range as those reported by Orr and Wogar (1979).

Statistical analyses of these data are presented in Table 13. When results are expressed on a meat basis, WHC is significantly decreased by the inclusion of either skin or MDTM. However, when expressed on a protein basis, no significant change resulted. This is probably due to a large standard deviation within sample measurements. The marginal values do appear, however, to decrease with a decrease in MDTM.

As discussed in the review of literature, heating of the fibrillar proteins cause shrinkage to occur. This shrinkage results in smaller

Table 11. Mean Percentage of Water Lost from the Total Meat Sample upon Heating from Meat Formulations Containing HDTM, MDTM and Turkey Skin

MDTM LEVELS (percent)	SKIN LEVELS (percent) 0	5	10	15	20	25	Marginals
75	51.88	52.27	52.96	55.94	53.49	53.41	53.32
65	49.71	52.52	52.63	53.49	48.81	50.80	51.33
55	50.59	50.66	50.12	50.78	51.79	48.37	50.39
45	51.59	48.73	50.23	49.24	47.35	45.44	48.76
35	46.78	47.51	50.91	50.85	49.51	42.83	48.06
25	45.40	47.45	47.60	48.16	45.55	44.43	46.43
Marginals	49.32	49.86	50.74	51.41	49.42	47.55	

Mean values of three replications.

Table 12. Mean Percentage of Water Lost per Gram of Protein upon Heating by Meat Formulations Containing HDTM, MDTM and Turkey Skin

MDTM LEVELS (percent)	SKIN LEVELS (percent) 0	5	10	15	20	25	Marginals
75	10.67	10.98	11.27	12.11	11.83	12.03	11.48
65	10.06	10.80	10.96	11.38	10.56	11.24	10.84
55	10.08	10.25	10.27	10.58	11.02	10.47	10.44
45	10.04	9.63	10.13	10.09	9.86	9.39	9.88
35	8.93	9.24	10.06	10.25	10.15	8.92	9.59
25	8.53	9.05	9.26	9.52	9.18	9.03	9.10
Marginals	9.72	9.99	10.32	10.66	10.43	10.06	

Mean values of three replications.

Table 13. Analysis of Variance of the Water Holding Capacity of Meat Formulations Consisting of HDTM, MDTM and Turkey Skin

Source of Variation	Degrees of Freedom	F Statistic	Significance
Meat Basis			
Main Effects			
Skin	5	4.37	.002
MDTM	5	15.01	.0005
Interactions			
Skin X MDTM	25	1.02	.454
Protein Basis			
Main Effects			
Skin	5	1.01	.415
MDTM	5	1.02	.415
Interactions			
Skin X MDTM	25	.97	.515

interstices and expression of bound water. This is the most common cause for the decreasing WHC in the majority of meats. Also during heating, collagen is converted to gelatin which has the ability to bind copious quantities of water. In this system, these two processes may occur simultaneously with the water forced from the fibrillar proteins being bound by the gelatin, the consequence being a negation of effects.

Emulsification Capacity

Mean values of the emulsification capacity (EC) for the meat combinations are summarized in Tables 14 and 15. Table 14 shows the results as milligrams oil emulsified per gram sample, whereas Table 15 shows the

Table 14. Mean Milligrams of Oil Emulsified per Gram Meat by Formulations Containing HDTM, MDTM and Turkey Skin

MDTM LEVELS (percent)	SKIN LEVELS (percent) 0	5	10	15	20	25	Marginals
75	139.84	124.74	128.12	105.78	107.02	106.95	118.74
65	145.05	144.09	134.38	118.03	113.22	98.92	125.61
55	160.19	138.92	123.53	134.00	113.44	97.72	127.97
45	152.17	137.77	140.54	136.27	125.93	130.48	137.19
35	158.04	149.68	138.92	133.05	140.16	124.03	140.65
25	149.40	159.11	137.73	133.08	123.08	136.31	139.78
Marginals	150.78	142.38	133.87	126.70	120.47	115.73	

Table 15. Mean Milligrams of Oil Emulsified per Gram Protein by Meat Formulations Containing HDTM, MDTM and Turkey Skin

MDTM LEVELS (percent)	SKIN LEVELS (percent) 0	5	10	15	20	25	Marginals
75	847.55	769.98	800.79	673.73	694.93	665.74	742.12
65	863.34	873.35	824.38	737.69	721.18	744.92	777.04
55	861.20	842.01	744.18	822.11	709.00	622.38	766.81
45	869.46	800.97	831.55	820.91	772.60	815.54	818.51
35	887.87	854.94	807.70	787.25	844.36	760.94	823.84
25	825.38	893.90	786.95	773.80	728.29	816.26	804.10
Marginals	859.13	839.19	799.26	769.25	745.06	720.53	

results as milligrams oil emulsified per gram of protein. Statistical analyses of the data is presented in Table 16.

Table 16. Analysis of Variance of the Emulsification Capacitiy of Meat Formulations Containing HDTM, MDTM and Turkey Skin

Source of Variation	Degrees of Freedom	F Statistic	Significance
Meat Basis			
Main Effects			
Skin	5	20.65	.0005
MDTM	5	9.17	.0005
Interactions			
Skin X MDTM	25	1.30	.194
Protein Basis			
Main Effects			
Skin	5	10.35	.0005
MDTM	5	3.66	.005
Interactions			
Skin X MDTM	25	1.34	.166

These results correspond to those reported by McMahon and Dawson (1976b) and fall within the upper half of EC values reported for similar meat types throughout the literature. Direct comparison of these values would be difficult because of the huge variations in reported results, as discussed in the literature review. It is my belief that these values are best used as a point of comparison between the meat samples analyzed within the scope of this study and as perhaps a rank ordering of EC reported from other studies.

Either analysis indicates that skin and MDTM both negatively affected fat emulsification. Skin was shown to have a greater adverse effect than MDTM.

The protein basis data were then used to construct a regression equation as follows:

$$EC = 932.27 - 5.74X_1 - 1.43X_2$$

X_1 = skin level in percent

X_2 = MDTM level in percent

Analyses of variance for the overall regression indicate that the regression equation accurately describes the role of the proteins in the formulation system (Table 17).

Table 17. Analysis of Variance for Overall Regression of the Emulsification Capacity of Formulations Containing HDTM, MDTM and Turkey Skin

	Degrees of Freedom	F Statistic	Significance	Correlation Coefficient
Regression	2	30.197	.0005	.6843

The regression coefficients indicate that skin was four times more detrimental to the EC than was MDTM (5.74/1.43 = 4.01). This seems to indicate that even severly ruptured and sheared myofibrillar proteins are capable of stabilizing more lipid than is the relatively unreactive collagen.

This regression equation can be used to predict the relative EC of formulations containing various levels of HDTM, MDTM and turkey skin. It is graphically illustrated in Figure 6. Any meat combinations falling

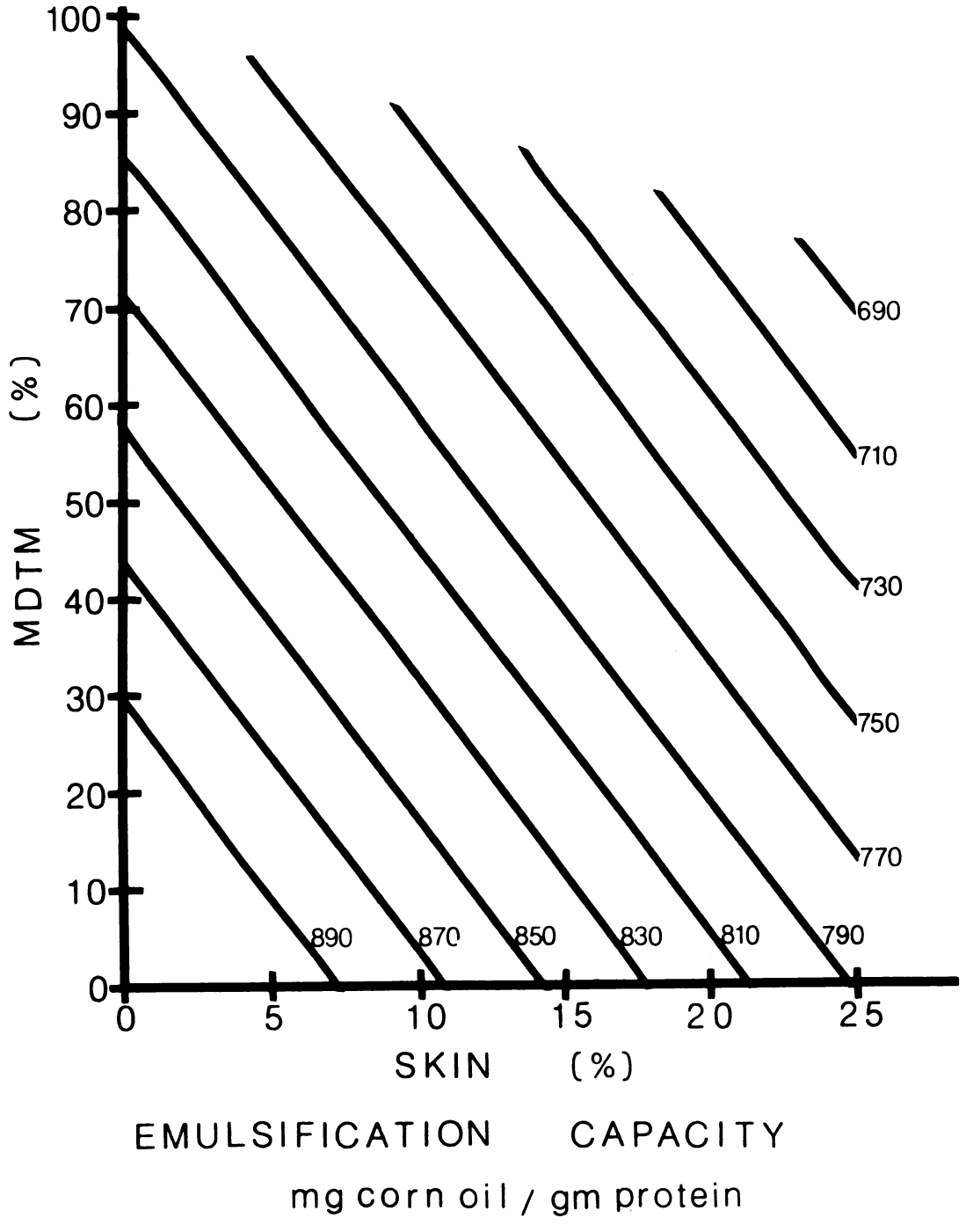


Figure 6. Emulsification Capacity of HDTM, MDTM and Turkey Skin Combinations as Predicted by Calculated Regression Equation (EC = 932.27 - $5.74X_1$ - $1.43X_2$).

along the same regression line should give equivalent emulsification capacities.

Sausage Manufacture

Sausage Formulations

Regression equations for WBC and EC were used to select four formulations for sausage manufacture. WHC was not included because no significent changes resulted from alterations in meat combinations.

Figure 7 illustrates the simultaneous solution of the two equations. The four formulations selected for further study are indicated by the stars. The exact formulations are given in Table 4 of the Methods section. They were selected so that treatments one and two and treatments three and four would display similar WBC, while treatments one and four and treatments two and three would display similar emulsification capacities. The calculated WBC and EC are given in Table 18.

Table 18. Water Binding Capacity and Emulsification Capacity of Meat Combinations Used for Sausage Formulation as Predicted by Regression Equations.

Treatment	Water Binding Capacity	Emulsification Capacity
1	3.4	831.1
2	3.4	781.5
3	3.0	780.1
4	3.0	831.2

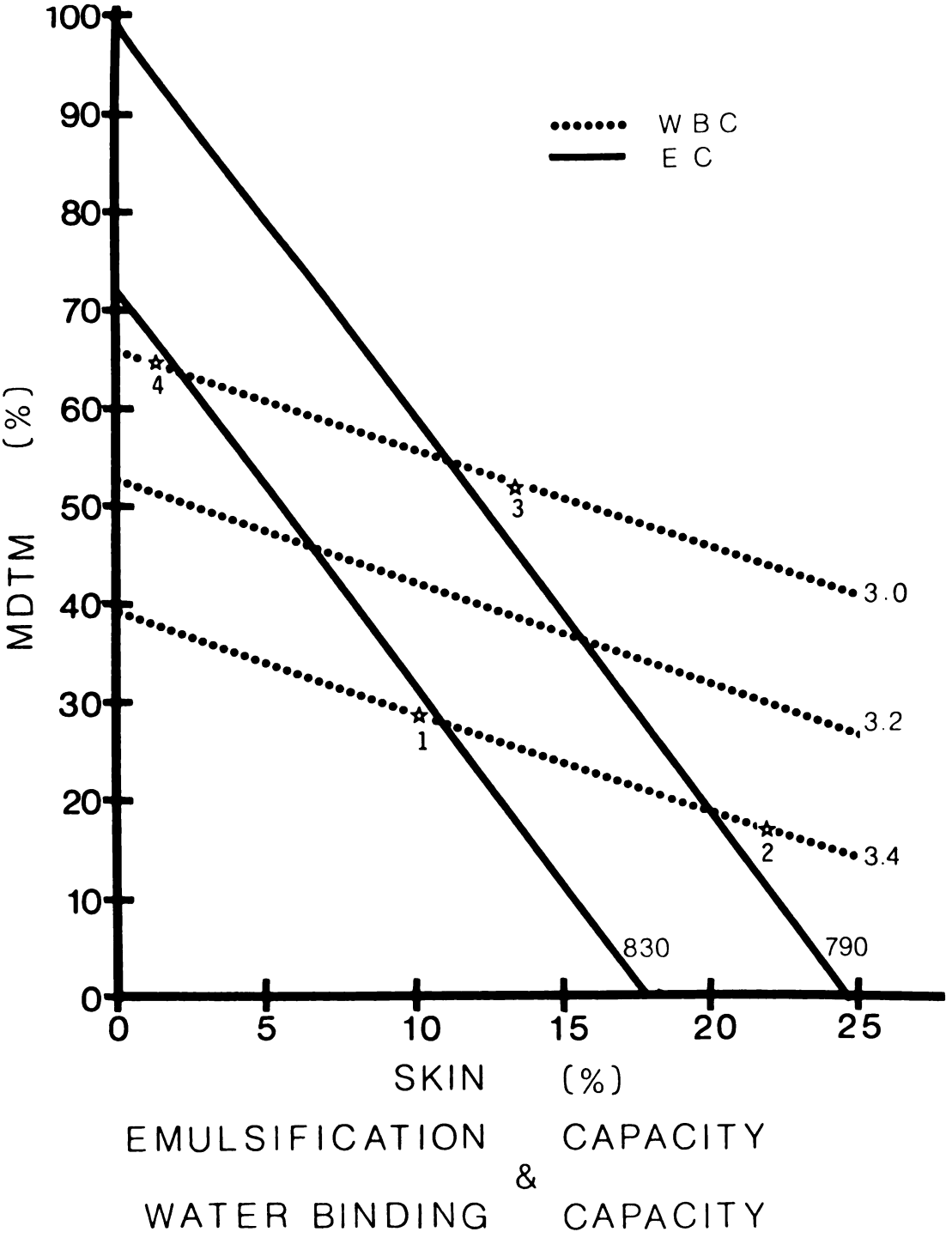


Figure 7. Emulsification Capacity and Water Binding Capacity of HDTM, MDTM and Turkey Skin as Predicted by Calculated Regression Equations. Stars Indicate the Four Meat Combinations Selected for Sausage Manufacture.

Proximate Composition

The proximate composition of the finished sausage is reported in Table 19. Statistical analyses of the data are presented in Table 20.

Table 19. Proximate Composition of Finished Frankfurters

Treatment	Protein	Moisture	Fat
	percent		
1	$10.16^{a} \pm .46$	$61.80^{c} \pm .47$	$21.51^{a} \pm .34$
2	$10.74^{a} \pm .47$	$60.30^{b} \pm .32$	$22.09^{b} \pm .52$
3	$10.54^{a} \pm .49$	$59.77^{a} \pm .27$	$22.68^{c} \pm .27$
4	$10.21^{a} \pm .54$	$60.25^{b} \pm .42$	$22.75^{c} \pm .30$

Values reported are means and standard deviations of three replicate samples. Values within columns that have the same superscript are not significantly different, as determined by Duncan's Multiple Range test.

Table 20. Analysis of Variance of the Proximate Composition of Finished Frankfurters

Source of Variation	Degrees of Freedom	Protein	Fat	Moisture
		percent		
		F Statistic		
Treatment	3	1.844	31.89^{**}	14.05^{**}
Batch	1	.433	.77	.01

The protein and fat levels of the finished frankfurters are both lower than the levels planned for during processing, approximately 10.5% and approximately 22% versus 12% and 25% respectively. The moisture content of the finished franks was about 61%, 5% higher than the proposed 56%. This lack of shrinkage may be accounted for by the water holding tenacity of the gelatin. As indicated by the functional tests, the gelatin is capable of holding large amounts of water, and it may be that at these formulation levels the holding properties are still strong enough to prevent the expected shrinkage.

Despite the elevated moisture content and the presence of skin in the frankfurters, no jelly pockets were seen on or within the sausage product. In addition, no unbound fat or other indicators of emulsion instability were seen during visual inspection.

Although statistical differences in fat and moisture levels were found between treatment groups, the differences are so small as to be insignificant from a standpoint of practical application. These small differences could be accounted for by unavoidable differences during processing, such as a piece of ice flying out of the chopper or meat "climbing out" of the machinery interior during the chopping and mixing procedure, rather than variation due to treatment.

No differences were seen in proximate composition between the two batches despite the fact that they were prepared on separate days yet cooked and smoked together. Evidently, no appreciable dehydration of the raw batter of batch number one occurred during the extra twenty-four hour holding period.

Because of the sampling technique, portions taken from the homogeneous batters gave significantly different compositional results

despite only minute variation. A different sampling technique would likely indicate that no differences existed in fat and moisture level of the four treatment groups.

Tenderness

The tenderness of the sausage interior was measured by shear force using an Allo-Kramer Shear Press. These tenderness evaluations are summarized in Table 21 and the statistical analysis is presented in Table 22.

Table 21. Tenderness of Hot and Cold Sausage Samples as Measured by an Allo-Kramer Shear Press

Treatment	Interior	
	Hot # force per gram meat	Cold # force per gram meat
1	.99[a]	1.79[b]
2	.97[a]	1.73[b]
3	.97[a]	2.02[b]
4	1.03[a]	1.84[b]

Values within columns that have the same superscript are not signi-significantly different, as determined by Duncan's Multiple Range test.

Table 22. Analysis of Variance of the Tenderness of Sausages Containing HDTM, MDTM and Turkey Skin as Measured by an Allo-Kramer Shear Press

Source of Variation	Degrees of Freedom	F Statistic	Significance
HOT			
Treatment	3	.8723	N.S.
Batch	4	.5893	N.S.
COLD			
Treatment	3	2.128	N.S.
Batch	4	5.0	.01

When the sausages were heated in a boiling water bath, they swelled considerably due to the expansion of air trapped within the sausage. This air was incorporated during the mixing period and was not removed by way of vacuum prior to stuffing, as is the common processing procedure, due to equipment inavailability. Although much of this swelling had receded prior to shearing, some puffiness was still evident. This stretching of the internal protein matrix and the presence of entrapped air could account for the considerable ease of the breaking of the heated samples as compared to the unheated samples.

Regardless of whether the sausages were sheared while in a hot or cold state, no differences in objective measurement were seen between the treatment groups. This indicates that the tenderness of the sausages were equivalent regardless of the type of protein in the meat. This supports the finding of Schnell (1973) who stated that increased skin level did not increase tenderness as measured by a shear press. It does not support the work of Baker (1968) who reported that sausage firmness increased if skin content exceeded 20%.

A difference in tenderness was seen between batches when cold sausages were sheared. Although this was not of primary concern for this project, a possible explanation may be that because the matrix stood for an extended time prior to denaturation (cooking), a more stable and thus stronger configuration was established.

Sensory Evaluation

Mean values of sensory evaluation scores for products from various treatments are summarized in Table 23. Statistical analyses of these data are presented in Table 24.

Table 23. Mean Sensory Scores of Turkey Sausages Containing HDTM, MDTM and Turkey Skin

Parameters	Treatment			
	1	2	3	4
Greasiness	4.47[a] ± 1.44	4.67[a] ± 1.23	4.59[a] ± 1.52	4.51[a] ± 1.62
Moistness	3.36[a] ± 1.33	3.50[a] ± 1.39	3.80[a] ± 1.28	3.52[a] ± 1.28
Elasticity	3.92[a] ± 1.46	3.34[a] ± 1.26	3.69[a] ± 1.24	3.45[a] ± 1.56
Cohesiveness	2.52[a] ± 1.31	2.92[a] ± 1.46	2.59[a] ± 1.41	2.42[a] ± 1.37
Uniformity	2.72[a] ± 1.26	3.65[b] ± 1.70	2.76[a] ± 1.55	2.99[a] ± 1.35

Scale = .05 (most) to 7.5 (least)

Values within rows that have the same superscript are not significantly different as determined by Duncan's Multiple Range test.

Table 24. Analysis of Variance of Sensory Scores on Turkey Sausages Containing HDTM, MDTM and Turkey Skin

Source of Variation	Degrees of Freedom	Greasiness	Moistness	Elasticity	Cohesiveness	Uniformity
		F Statistic				
Treatment	3	.152	.937	1.48	1.14	3.80**
Batch	1	.211	.080	.00	1.02	1.46

Taste panelists were unable to detect any differences in the treatments in any of the four parameters: greasiness, moistness, elasticity or cohesiveness. Differences were detectable in the uniformity of the product, with the sample containing 22% skin being differentiated from the others. Although asked, taste panelists could not or did not define the nature of the non-uniformity. Due to its fibrous nature, it is extremely difficult to chop skin as finely as muscle tissue, therefore the particle size remains large. It might be that at this higher skin level the somewhat larger particle size of the chopped skin is more noticeable.

Taste panelists were asked to rank the four treatment samples for their "degree of juiciness". This was done to determine if a relationship existed between juiciness and moistness and/or greasiness. No significant ranking was agreed upon by the panelists; samples were found to be equivalent in juiciness as they were in moistness and greasiness.

Generally no differences could be detected by objective or subjective methods to differentiate the four samples, despite the prediction that differences in water binding and emulsification capacity of the meat combinations would affect the product. This lack of difference may exist because measurement of WBC and EC result in a prediction of the extreme. For example, 3.4 milliliters is the maximum amount of water which can be bound by a hypothetical system and 790 milliliters oil is the maximum amount of oil which can be emulsified by a hypothetical system. Using small laboratory scale product batches, these extremes may not have been approached. The conditions for processing were optimal. The meat and fat were very cold, and the machinery and equipment were at room temperature, not heated from prior use. Consequently, even after

chopping, the meat temperature was still quite low, thus preventing a phase change in the fat (solid to liquid) or premature denaturation of the protein.

Chop time was well monitored to assure that "overchopping" did not occur. This would have caused the formation of smaller and more numerous fat globules resulting in an increased surface area for the proteins to envelope.

Only minimal manipulation of the product occurred and then it was handled in a gentle manner. Because the batches were small (approximately 15 pounds), the processing, stuffing, linking and hanging all proceeded without delay. Therefore, no warming of the product could have occurred during a holding interval causing a stress on the system.

Smokehouse temperature, humidity and air velocity were carefully controlled to prevent any shock to the emulsion as it heated. Sudden and unnecessary condition changes were avoided.

In addition to optimal processing conditions, the composition of the sausages was well within the limitations in which instability would have occurred. A fat content of 22%, as existed in this product, is considered quite lean. A moisture content of 60% also is not taxing to the system, particularly considering that the added seasoning contains hydrophilic carbohydrates. With this formulation under these optimal conditions, the performance of the proteins fell well within their functional capabilities. Perhaps differences would have been evident if the processing conditions or formulation composition were less optimal. Because the stability parameters were easily met, no differences were detectable.

Under commercial conditions where some of these stress situations do occur, these prediction equations should be useful in producing a high quality, consistent product.

SUMMARY

Product and residue from mechanically deboned turkey racks and backs, some stripped of visible skin and some unstripped, were analyzed to determine whether the skin was expressed with the edible product or with the inedible residue portion, using a collagen quantification method. Regardless of whether or not the carcass was stripped of skin, 8-14 mg collagen per gram of meat was contained in the product sample, the bulk of the collagen remaining with the bone residue.

HDTM, MDTM and turkey skin combinations were evaluated in an emulsion system for their functional properties; water binding, water holding and emulsification capacities. HDTM levels ranged from 0% to 75% (5% intervals), MDTM levels ranged from 25% to 75% (10% intervals), and skin levels ranged from 0% to 25% (5% intervals). In all, thirty-six meat combinations were investigated.

Water binding capacity was found to be detrimentally affected by the inclusion of MDTM or turkey skin in the system. Their negative impact was calculated to be nearly equivalent by way of regression analysis. No interactions were found to exist.

Water holding capacity of the meat combinations decreased as MDTM or skin levels were increased within the system when the results were expressed on a meat basis, but not when they were expressed on a protein basis. Thus it was concluded that the proteins from MDTM and skin were capable of holding water and that the negative impact was due to other factors in the system, perhaps fat.

The emulsification capacity of the various meat combinations was also negatively affected by the inclusion of MDTM or turkey skin to the emulsion system. However, skin was four times more detrimental to the EC than was MDTM as calculated by regression analysis.

Using the results from the investigation of the functional properties of the meat, four combinations were selected for manufacture into frankfurters: 1) 28.5% MDTM, 61% HDTM and 10.5% skin; 2) 17% MDTM, 61% HDTM and 22% skin; 3) 52% MDTM, 34.5% HDTM and 13.5% skin; 4) 64.5% MDTM, 34% HDTM and 1.5% skin. Treatments 1 and 2 and treatments 3 and 4 were chosen as they displayed similar WBC, whereas treatments 1 and 4 and treatments 2 and 3 displayed similar EC.

Analysis of the proximate composition of the finished sausages revealed significant but minute differences in the fat and moisture content of the frankfurters. These differences were attributed more to the preparation and sampling technique rather than the protein's function.

Hot and cold frankfurters were evaluated for tenderness using an Allo-Kramer Shear Press. No differences were observed between treatments in the objective measure of tenderness.

Taste panelists were utilized to subjectively evaluate greasiness, moistness, elasticity, cohesiveness and uniformity of the sausage, utilizing a nonnumeric, continuum style scale. Each panelist also ranked the four samples on the basis of their juiciness. No differences were apparent through evaluation in any sensory parameter except for uniformity. There was some perceived difference in the uniformity of treatment two, although panelists did not identify the point of differentiation. Treatment two did contain the highest amount of skin and the difficulty

in finely chopping the tissue may have resulted in the lack of homogeneity reported.

This experiment illustrated that HDTM, MDTM and skin could be used together in various proportions to produce sausages of equivalent quality. This information can be useful for commercial processing where cost and material availability fluctuations make formulation manipulation highly desirable. Quantification of the functional characteristics and transformation of the data into regression equations make linear programming and other computer-assisted applications possible.

APPENDIX

I N S T R U C T I O N S

You will be presented with four sausage samples. Please evaluate each sausage on the characteristics indicated. Use one score sheet for each sample. Indicate your score by placing an X on the line where you feel the sample falls between the extremes listed. As a reference for your scoring, use your own concept of the characteristics of an ideal sausage of this type.

In addition, please rank the four samples on the basis of their juiciness. Juiciness for our purpose will be the "degree of liquid released upon chewing" and is a result of the combined effect of both water and fat. Use the small score sheet for this ranking.

The sausage casing is not a part of this evaluation. It has been split to aid in its removal.

If you notice an air pocket in the sausage, please disregard it in making your evaluation.

This sausage contains no ingredient that is atypical to a cured sausage product of this type.

Thank you for helping with this research project.

NAME _____

SAMPLE # _____

GREASINESS most greasy ——— least greasy

MOISTNESS watery ——— dry

ELASTICITY most rubbery ——— least rubbery

COHESIVENESS good bind (cohesive) ——— poor bind (crumbly)

UNIFORMITY uniform consistency (homogenous) ——— variable consis-tency (heterogenous)

If variable consistency exists please check the applicable description

_____ gritty

_____ fibrous

_____ coarse

_____ other (please specify)

NAME _____

DATE _____

Please rank the four samples for juiciness. The sample that is the most juicy is ranked #1, the sample which is the least juicy is ranked #4.

_____	_____	_____	_____
#1	#2	#3	#4

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