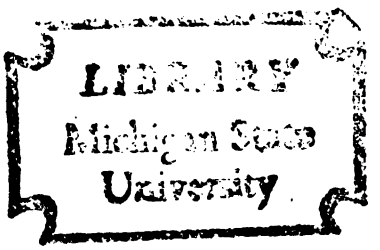
STUDIES INVOLVING UTILIZATION AND STABILITY OF MECHANICALLY DEBONED TURKEY MEAT

Dissertation for the Degree of Ph. D.

MICHIGAN STATE UNIVERSITY

MARK ALAN UEBERSAX

1977



This is to certify that the

thesis entitled

Studies Involving Utilization and Stability of Mechanically Deboned Turkey Meat

presented by

Mark Alan Uebersax

has been accepted towards fulfillment of the requirements for

Ph.D. degree in Food Science & Human Nutrition

L. E. Dawson

Major professor

Date January 28, 1977

ABSTRACT

STUDIES INVOLVING UTILIZATION AND STABILITY OF MECHANICALLY DEBONED TURKEY MEAT

By

Mark Alan Uebersax

The storage stability of mechanically deboned turkey meat (MDTM) was evaluated in a series of three studies. The first study included physical and chemical evaluations of MDTM substituted turkey loaves. Loaves were prepared using hand boned breast meat with MDTM substituted at 0%, 10%, 20%, and 30% by weight. Physical and chemical evaluations included proximate composition, mineral analysis, cooking yields and loaf dimensions, surface color and texture of crosscut slices. Compositional changes generally reflected ingredient blends. Cook yield and loaf size were improved with increased levels of MDTM. The surface color (Hunter Lab) was darker and more red in color with increasing MDTM. Texture was evaluated by slice breaking (binding strength) and by slice shearing (tenderness) using an Instron Press. Slices possessed less binding strength and were more tender with increased MDTM.

Storage stability of formulated loaves was evaluated by the 2-thiobarbituric acid test (TBA) and sensory

analyses. Raw and precooked foil wrapped MDTM substituted loaves held at 4°C one week resulted in decreased TBA numbers with increased meat substitution and increased TBA numbers for precooked loaves. Sensory evaluation did not satisfactorily distinguish flavor differences. Additional loaves were stored raw and precooked, foil wrapped and vacuum sealed, at -18°C six months prior to analysis. TBA numbers increased with increased MDTM and precooking and decreased with vacuum packaging. Sensory evaluation indicated increased moistness and more tender loaves with increased MDTM. Cooking and packaging treatments were distinguished using the triangle test for 10% MDTM substitution.

The second study involved in vivo tocopherol supplementation of turkeys. Turkey diets were supplemented at 100 I.U. alpha tocopherol acetate above basal rations from 12 weeks of age through slaughter (females, 18 weeks; males, 20 weeks). Additional turkeys were supplemented through 100 I.U. biweekly injections. Breast, thigh, and MDTM were held at 4°C one week or stored at -18°C up to three months. Samples from tocopherol treated birds had significantly lower TBA numbers than controls. TBA numbers of breast meat were lower than those from MDTM and thigh meat. TBA numbers of meat from females were lower than those from males. Loaves prepared from breast meat and MDTM were foil wrapped and vacuum sealed, held at 4°C one week and other loaves stored at -18°C up to six months.

Both tocopherol supplementation and vacuum packaging independently maintained meat with low TBA numbers. Loaves prepared from tocopherol supplemented meat and then vacuum packaged had lowest TBA numbers under all conditions.

The third study involved the addition of antioxidant treatments directly into MDTM. Four commercial phenolic antioxidant mixtures, EDTA, Kena® (commercial polyphosphate), and citric and ascorbic acids were evaluated under different conditions. Generally, phenolic antioxidant treated MDTM had lower TBA numbers than MDTM receiving other treatments.

Conclusions from these studies showed that MDTM could be utilized in the formulation of high quality products and that the storage stability of MDTM could be improved with appropriate treatments and handling. Vacuum packaging offered a major advantage in decreasing TBA numbers.

STUDIES INVOLVING UTILIZATION AND STABILITY OF MECHANICALLY DEBONED TURKEY MEAT

By

Mark Alan Uebersax

A DISSERTATION

Submitted to

Michigan State University

in partial fulfillment of the requirements

for the degree of

DOCTOR OF PHILOSOPHY

Department of Food Science and Human Nutrition

1977

to my friend Kristen

ACKNOWLEDGMENTS

The author extends sincere appreciation to his major professor, Dr. L.E. Dawson, for his personal interest and professional guidance throughout this degree program.

Grateful acknowledgment is due the members of the research guidance committee: Dr. L.L. Bieber, Biochemistry; Dr. D. Polin, Poultry Science; Dr. J.R. Kirk and Dr. M.E. Zabik, Food Science and Human Nutrition.

Special mention is made to Dr. G. Malcolm Trout, whose enlightened and professional attitude is infectious.

Appreciation is expressed to Dr. G.A. Leveille, Chairman, Food Science and Human Nutrition, for making facilities and financial support available for this research.

The Institute of Food Technologists and its Great Lakes Section are both again thanked for financial assistance.

A hardy thank you is given to Kristen Uebersax, research assistant, for aid in performing the analytical determinations, as well as for typing this manuscript.

The author has difficulty in expressing the heartfelt gratitude due those that are closest to him. Excluding that first due Kristen, he expresses deepest gratitude to his parents for their love and many sacrifices, and to Kristen's parents for their enthusiasm and encouragement.

TABLE OF CONTENTS

LIST OF TABLES

Table | Page

Table Page

Table Page

Table Page

LIST OF FIGURES

Figure Page

LIST OF PLATES

INTRODUCTION

Further processing of poultry products (marketed other than as whole birds) has increased dramatically during the past two decades. Traditionally, turkeys were sold as whole birds for roasting; however, in recent years more centralized processing and greater consumer demand for convenience foods have led to increased production of further processed turkey products. These products include: cut-up parts, fabricated loaves and rolls made from hand boned breast and thigh meat, and emulsion items such as bologna and frankfurters. Total supply of turkeys has increased from 385 million pounds in 1965 to about 800 million pounds in 1976 (Anon., 1976a). It has been suggested that 25% to 30% of the turkey crop has been sold as rolls and loaves (Baker, 1976).

The advent of mechanical deboning operations has contributed greatly to this increase. Several types of mechanical deboning machines are commercially available and find wide use in deboning poultry meat (Martin, 1974; Dawson, 1975; Froning, 1976). The deboning process is an economical means of salvaging high quality protein from under-utilized portions (necks and backs) or waste products (hand boned racks) obtained in the poultry processing

industry. Obtaining economical and high quality protein has been of growing concern in meeting world protein needs.

The deboning process involves crushing or pre-grinding these portions and expressing them through a sieve. Meat passes through the sieve and is thus separated from the bone residue. Mechanically deboned meat is characterized by its paste-like consistency and high susceptibility to deteriorative changes which occur during storage. The extreme stress and aeration during the process and the compositional nature (bone marrow, heme, and lipids) of the product contribute to its high oxidative potential. Turkey meat is composed of relatively high levels of unsaturated fatty acids and low levels of natural tocopherols making it further unstable. Stabilizing the color and flavor, and defining functional properties have been of foremost concern. Diminishing these problems will encourage and stimulate wider utilization of mechanically deboned meat.

The purpose of this investigation was to define more clearly and to improve the storage stability of mechanically deboned turkey meat (MDTM). Three independent studies were conducted. The first study was undertaken to evaluate the physical and chemical composition of MDTM substituted turkey loaves. Products were formulated with different levels of MDTM and evaluated raw and precooked under various packaging and temperature conditions. The second study was that of in vivo tocopherol supplementation and subsequent storage stability evaluation of turkey meat

and MDTM formulated loaves handled under various packaging and temperature conditions. The third study involved the direct addition of various antioxidants to MDTM in an attempt to improve storage stability.

REVIEW OF LITERATURE

Lipid Oxidation

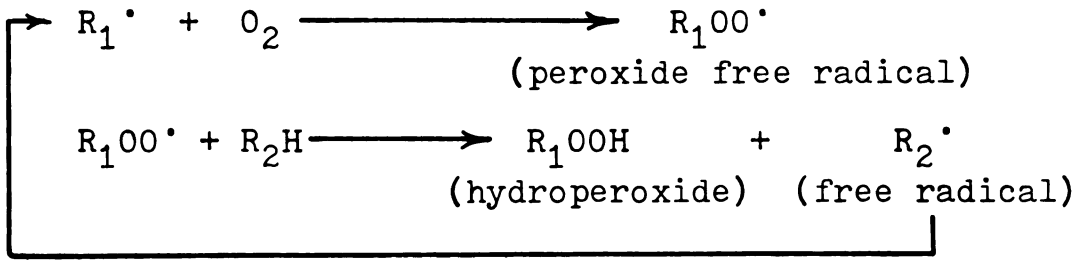
Oxidative deterioration of food lipids has been shown to be responsible for the development of "rancid" flavors (Dugan, 1961). Oxidative rancidity resulting in quality and nutritional loss may be the single most deteriorative process occurring in food systems (Dugan, 1968). Intensive research efforts have been directed toward better definition and control of the lipid oxidative processes (Schultz, Day, and Sinnhuber, 1962). Complex mechanisms and numerous factors contribute to lipid deterioration. The generally accepted mechanism of lipid oxidation has been reviewed by Dugan (1961), Labuza (1971), and Sato and Herring (1973) and involves a free radical chain reaction, which proceeds in three stages, as follows:

initiation--the formation of a free radical species (unpaired electron) from an unsaturated fatty acid,

$$R_1H \xrightarrow[\text{(heat, light, metals, } O_2\text{)}]{\text{initiators}} R_1\cdot \text{ (free radical)} + H\cdot$$

propagation--free radicals combine with molecular oxygen (autoxidation) to form peroxide free radicals which

upon reaction with fatty acids yield hydroperoxide and another free radical, available to continue the chain reaction,



termination--deactivation of the free radical resulting in stable end products,

$$R^{\bullet} + R^{\bullet} \longrightarrow RR$$
$$R^{\bullet} + ROO^{\bullet} \longrightarrow ROOR$$
$$ROO^{\bullet} + ROO^{\bullet} \longrightarrow ROOR + O_2$$
$$R^{\bullet} + R_I \longrightarrow RR_I$$

Free radical inhibitors (R_I) include antioxidants.

The development of off-flavors results from hydroperoxide degradation. Hydroperoxides, though themselves odorless, degrade through a series of scission and dismutation reactions to yield low molecular weight carbonyl compounds (aldehydes and ketones) and short chain fatty acids which possess extremely low sensory threshold values.

Factors which affect the rate of off-flavor development include fatty acid composition of lipid, temperature, light, metal catalysts, inhibitory compounds, and availability of oxygen (Lea, 1962; Labuza, 1971). It is important to consider all of these factors in stabilizing

lipid oxidation. Ackman (1976) simplistically emphasized two major points when discussing lipid stability of foods: first, the need to begin with a high quality raw material, and second, the need to optimize all handling and storage procedures.

Labuza (1971) reviewed the kinetics of lipid oxidation in foods and classified antioxidant agents into three general types, as previously classified by Scott (1965). Type I are free radical terminators, compounds which donate hydrogen to the free radical and thus stop the chain reaction. This group comprises primarily phenolic type compounds such as butylated hydroxyanisole (BHA), butylated hydroxytoluene (BHT), and tocopherol. Type II are free radical preventors, compounds which control the production of free radicals during the initiation stage. Metal-complexing agents which chelate catalytically reactive metals are included in this classification. Ethylene-diaminetetraacetic acid (EDTA), citric acid and ascorbic acid function primarily as metal chelators. Type III are environmental factors, physical conditions such as temperature and packaging materials which influence the rate of oxidative reactions.

Commerical phenolic antioxidants (Type I) have been widely used in the food industry (Dugan, 1960). Mechanisms and their commercial use have also been reviewed (Stukey, 1962, 1968). Pokorny (1971) reviewed the use of phenolic antioxidants in stabilizing fats and stated that phenolic

antioxidants reacted with free radicals and resulted in a non-propagating end product. The rate of hydroperoxide formation (and resulting amount of subsequent breakdown products) would, thereby, be reduced.

Properties and formulations of common commercial phenolic antioxidants, many prepared with citric acid due to synergistic activity, have been summarized (Anon., 1976b). Application of commercial antioxidant mixtures to meat and poultry products has been reported (Anon., 1970). These may be applied directly into the food by dilution, applied as a spray, or added to packaging materials. One major problem with the use of antioxidants has been a failure to obtain their complete dispersion in the food system. This is particularly difficult in flesh type foods due to high moisture and dispersed fat (Nickerson, 1967; Stukey, 1968). Lund, Lindsay, and Branen (1976) reported difficulty obtaining uniform distribution of antioxidants when using several techniques of application.

Most phenolic type antioxidants are decomposed or distilled during cooking; however, BHA has relatively high heat process "carry over" (Nickerson, 1967).

Toxicology and the metabolic fate of BHA and BHT have been recently reviewed (Branen, 1975). Branen reported that the estimated daily human consumption of BHA and BHT was 0.1 mg/kg body weight. Daily intakes of 50 mg/kg body weight appear to be free of deleterious effects.

The principles of metal ion catalyzed lipid oxidation

have been reviewed (Ingold, 1962, 1968; Waters, 1971). Lipids contain heavy metals resulting from metal activated enzymes (Ingold, 1962) and from contamination by contact with metal during processing (Patron, 1968). Heavy metals, notably iron and copper, with several valency states generally increase the rate of oxidative reaction. Metals can affect the rates of initiation and propagation reactions and hydroperoxide degradation (Ingold, 1962). Type II antioxidants function primarily as chelating agents rendering metal ions unavailable for initiation. The metal chelating properties of EDTA and its use in food have been reviewed (Furia, 1964). Citric acid has been used commercially to chelate heavy metals in various fats (Swisher and Swisher, 1967). Ascorbic acid will chelate metal ions; however, the mechanism of antioxidant activity is more complex in high moisture systems (Labuza, 1971). Cort (1974) presented an oxygen scavenger mechanism of ascorbic acid for increasing stability in oil systems. Ascorbic acid has shown prooxidant activity in meat (Love and Pearson, 1971; Benedict, Strange, and Swift, 1975). Citric and ascorbic acids have shown beneficial synergistic effects with Type I antioxidants (Dugan, 1961). Polyphosphates have been classified as metal chelating agents (Deman and Melnychyn, 1971).

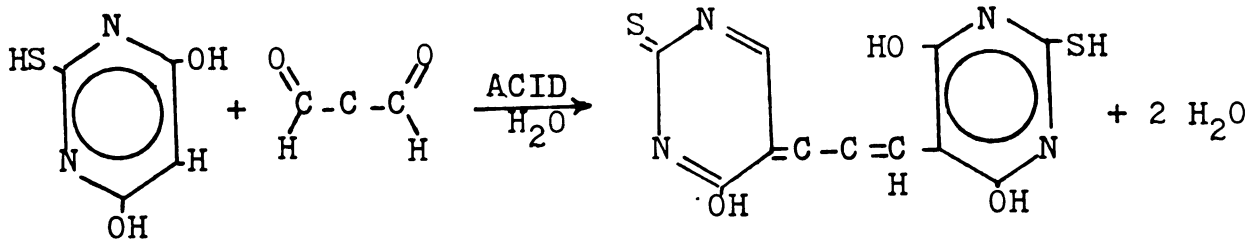
It is generally accepted that lipid oxidation proceeds at higher temperatures, hence the use of low temperature storage. Packaging materials and methods as Type III

TBA Test

antioxidants may be used to reduce the partial pressure of oxygen within the packaged product (Ball, 1967; Labuza, 1971).

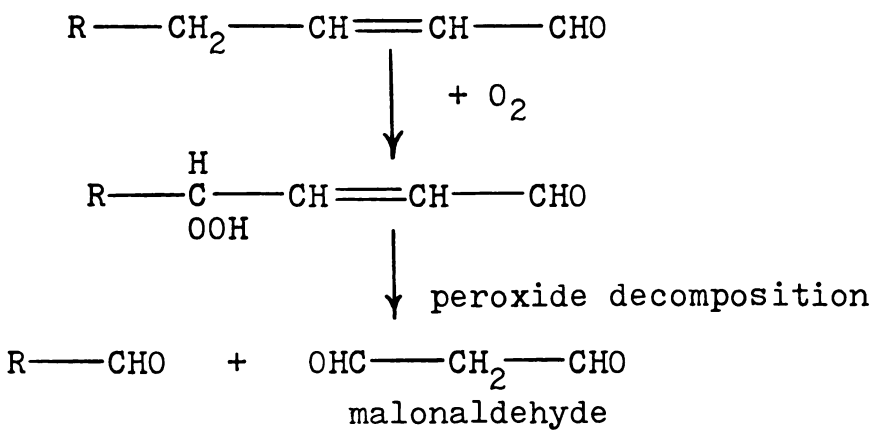
Kinsella et al. (1975) reviewed numerous problems which exist in collating and interpreting data concerning lipids in food systems. Problems emphasized included inherent variability of species; variable processing, cooking, and storage changes; and sampling and analytical limitations.

Sherwin (1968) reviewed methods of determining the stability of fats and oils in foods. Current methodology available for the evaluation of the storage stability of lipids in foods was reviewed by Erickson and Bowers (1976). These workers classified methods of determining lipid stability as the measurements of oxygen uptake, peroxide formation, and peroxide decomposition or final reaction products. The 2-thiobarbituric acid test (TBA) was classified as a means to measure final reaction products. This method has been used in foods under a variety of test conditions for determining the extent of lipid oxidation (Turner et al., 1954; Tarladgis et al., 1960; Tarladgis, Pearson, and Dugan, 1964). The method has been based on the development and quantitation of a red pigment formed by the condensation of one molecule of malonaldehyde and two molecules of 2-thiobarbituric acid. The condensation occurs as follows (Sinnhuber, Yu, and Yui, 1958):



TBA MALONALDEHYDE TBA PIGMENT

The chemistry of the pigment has been studied (Sinnhuber, Yu, and Yui, 1958; Tarladgis, Pearson, and Dugan, 1962; Yu and Sinnhuber, 1962; Marcuse and Johansson, 1973) and maximum absorbance of the red pigment has been shown to occur at 530 nm to 535 nm (Sinnhuber, Yu, and Yui, 1958). The proposed mechanism of malonaldehyde formation is by dismutation and scission of aldehydes generated during hydroperoxide degradation, as shown below (Day, 1966):



Concern has been expressed over test conditions altering malonaldehyde; therefore, empirical techniques must be followed. Erickson and Bowers (1976) stated that malonaldehyde production during test conditions was of

academic interest but had no bearing on the utility of the method in the evaluation of rancidity. Fresh meats do not produce positive TBA reactions (Watts, 1962). Watts (1962) also suggested that TBA reactive substances have an important relationship to the sensory detection of rancidity. Off-flavor threshold values have been reported for TBA numbers in the range of 0.5 to 1.0 (Tarladgis et al., 1960; Watts, 1962). However, this range has not been firmly established, and inconsistent correlations between TBA numbers and sensory flavor scores exist. The TBA test is particularly useful because it can be performed on intact food samples without prior lipid extraction (Watts, 1962; Erickson and Bowers, 1976). Patton (1974) referred to the TBA test as highly sensitive and useful in monitoring lipid oxidation; however due to the complex nature of TBA pigment production, the results need to be interpreted with caution. In summation of a round table discussion concerning prediction of fat stability, Dugan (1976) stated that, of all objective methods available for determining lipid stability, each one had its limitations; therefore, sensory methods are necessary for confirmation.

Storage Stability of Poultry Meat

The oxidative deterioration of lipids in meats has been extensively studied and reviewed (Watts, 1962; Love and Pearson, 1971; Sato and Herring, 1973; Greene and Price, 1975). The storage stability of frozen poultry meat

has been reviewed by several researchers (Dawson, 1969; Stadelman, 1974; Cunningham, 1975).

The fatty acid composition of the lipid has been shown to be a major consideration in storage stability. The rate of oxidative reactions increases dramatically as the degree of unsaturation of fatty acids increases. These rate increases are a result of a greater sensitivity of the carbon-carbon double bond due to adjacent methyl groups (Labuza, 1971). High levels of unsaturated fatty acids have been reported for poultry and turkey meat (Scott, 1958; Acosta, Marion, and Forsythe, 1966; Wangen, Marion, and Hotchkiss, 1971). Phospholipids, though present in relatively small amounts, comprise extremely high levels of polyunsaturated fatty acids. Acosta, Marion, and Forsythe (1966) reported in a detailed study the evaluation of total and phospholipids of turkey meat. Higher phospholipids were shown for thigh meat than breast meat.

Marion and Forsythe (1964) reported higher TBA numbers in dark turkey meat (thigh) than in light meat (breast) held at $4^{o}C$ up to seven days.

Hartung and Froning (1967) reported lipids of male turkeys were less stable than of female turkeys.

Stadelman (1974) reviewed the storage stability of turkey meat and did not attempt to estimate the shelf life of turkey rolls because that is largely determined by product formulation.

Hooper, Goertz, and Mitchell (1965) reported flavor

stability of precooked turkey rolls which were stored at -18°C six months.

Essary and Rogers (1968) reported sensory flavor deteriorated in turkey rolls stored at -29°C up to eight months and under fluctuating temperature conditions. Dark meat scored lower than light meat.

Cash and Carlin (1968) reported increased TBA numbers and the development of off-flavor for precooked turkey rolls stored at -18°C up to 11 months.

Taylor, Smith, and Mitchell (1965) reported the importance of a low oxygen permeable packaging film in maintaining frozen storage stability of turkey steaks. The use of skin did not lower the quality of turkey steaks prepared from either light or dark meat.

Smith and Bowers (1972) studied the eating quality of precooked and freshly cooked turkey roulades stored at -23°C up to eight weeks. Fresh samples had superior flavor quality and lower TBA numbers than precooked samples. A commercial phosphate improved product acceptability.

Keskinel, Ayres, and Snyder (1964) reported increases in TBA numbers with grinding and holding at 5°C up to three weeks for a variety of meats. TBA numbers of raw ground turkey meat increased with holding time to a much greater extent than red meat studied. Turkey dark meat had significantly higher TBA numbers than light meat.

Martinsen and Carlin (1968) reported no increased TBA reaction during storage of precooked turkey; however, a

trained sensory panel indicated a significant decrease in flavor scores.

No significant differences in TBA numbers between precooked and freshly braised turkey breast were found by Cipra and Bowers (1976). Sensory evaluation indicated a more intense meaty-brothy aroma and flavor in fresh cooked breast. Precooked samples were scored as having a stale-rancid flavor.

Bowers (1972) reported no differences in TBA numbers among freshly cooked, microwave reheated, and conventionally reheated turkey breast muscle; however, all cooked meat had significantly higher TBA numbers than raw meat.

Johnson and Bowers (1974b) reported lower TBA numbers for freshly cooked turkey breast meat than precooked meat stored at -13°C for five weeks. Phosphate treated precooked and freshly cooked meat had lower TBA values than the control.

Jacobson and Koehler (1970) evaluated flavor and TBA reaction of cooked poultry meat after cooking and following refrigerated (4°C) and frozen (-20°C) storage. Light turkey meat had lower TBA numbers and higher sensory scores than dark meat. Holding cooked meats at 4°C up to four days resulted in increased TBA numbers and decreased sensory scores. The addition of propyl gallate reduced TBA numbers for all conditions.

Dimick and MacNeil (1970) reported changes in carbonyl compounds of cooked turkey skin fractions (oil and residue)

with storage time and temperature. Lower storage temperatures dramatically reduced the development of carbonyl compounds. Sensory and TBA analyses of cooked turkey skin fractions (MacNeil and Dimick, 1970b) held at 4.4°C up to 18 weeks resulted in a greater increased TBA reaction in the residue than in the oil. Sensory panels discriminated between fresh and stored residue after three weeks and between fresh and stored oil after seven weeks at 4.4°C.

Dawson and Schierholz (1976) reported that increased TBA numbers for ground turkey meat patties held at 4°C for seven days were associated with the addition of skin, cooking, and storage time.

Dawson, Stevenson, and Gertonson (1975) reported that turkey patties prepared from ground thigh meat and treated with commercial antioxidants had lower TBA numbers than controls during holding at 3°C up to 10 days; however, only slight differences in sensory scores were noted.

Klinger and Stadelman (1975) evaluated the flavor of reheated duck treated with various antioxidants using TBA and sensory analyses. TBA numbers of duck roasts treated with a mixture of propyl gallate, citric acid, Kena and alpha tocopherol, cooked and held at 8°C five days were all significantly lower than the reheated control. The only treatment not different from the control was citric acid when used alone. Taste panel evaluations did not distinguish antioxidant treatments.

The use of Vitamin E as a food additive was recently reviewed by Witting (1975). Tocopherols are not the most effective phenolic antioxidants (Benedict, Strange, and Swift, 1975).

Turkey meat has been shown to possess lower levels of natural tocopherol than other poultry meats. Mecchi, Pool, and Klose (1953) reported that the lower tocopherol content of turkey meat compared to chicken may be the single fat component responsible for greater storage stability of chicken meat. Fatty acid composition between the species was reported to be similar. Mecchi et al. (1956a,b) reported dietary tocopherol supplementation of turkeys (0.1% tocopherol added as D-alpha tocopherol acetate fed five and 10 weeks prior to slaughter) reduced peroxide values and total carbonyl production and increased flavor scores (decreased rancidity) for birds stored at -12.2°C for nine months. Turkeys receiving longer supplementation were superior.

Webb, Marion, and Hayse (1972a) reported lower TBA numbers for turkey meat obtained from turkeys fed or injected 10 I.U. or 100 I.U. of alpha tocopherol acetate. Mechanically deboned turkey meat (MDTM) from turkeys receiving tocopherol, held at 5°C up to seven days, was consistently lower than the control. Turkey breast and thigh meat both showed reduced TBA numbers raw, after cooking, and after precooked storage at -25°C for four months.

Webb, Marion, and Hayse (1972b) reported that turkeys receiving tocopherol supplementation, at 10 I.U. and 100 I.U. per pound of ration from eight weeks through slaughter, had significantly lower TBA numbers for cooked meat.

Hayse, Marion, and Paulson (1974) reported dietary supplement of 100 I.U. alpha tocopherol acetate per pound of ration fed throughout four weeks prior to slaughter decreased TBA numbers in MDTM held at refrigerator temperatures. No significant differences in sensory scores were obtained among various levels of supplementation for precooked turkey meat stored at -15°C for seven months.

Marusich et al. (1975) reported feeding male and female turkeys alpha tocopherol acetate levels of 100 I.U., 200 I.U., and 400 I.U./kg of feed one to four weeks prior to slaughter. Results showed a significant reduction in TBA numbers of meat. Optimum supplementation was obtained at 200 I.U./kg for four weeks. TBA numbers and tissue alpha tocopherol levels were correlated.

Brekke et al. (1975) reported more effective control of rancidity in rendered fowl fat using in vitro tocopherol addition than in vivo supplementation.

Mechanically Deboned Poultry Meat

The most recent and comprehensive review of compositional and functional properties of mechanically deboned poultry meat (MDPM) has been prepared by Froning (1976). Considerable inherent variability in proximate composition

of MDPM has been reported and attributed to the source of the meat, the meat to bone ratio, cutting and trimming methods, and deboning operations (Goodwin et al., 1968; Froning, 1970; Froning et al., 1971; Froning and Janky, 1971; Grunden, MacNeil, and Dimick, 1972; Froning and Johnson, 1973).

Schnell (1972) reported that yields varied inversely with deboner screen size and that composition varied with screen size and the source of meat deboned. Decreasing screen size resulted in decreased moisture, protein, and ash, and increased fat levels.

Mechanically deboned poultry meat from different sources has been shown to have lower protein and higher fat contents than hand boned meat (Froning et al., 1971; Grunden, MacNeil, and Dimick, 1972; McMahon and Dawson, 1976).

The influence of skin content during deboning of chicken backs was reported to directly affect product composition (Satterlee, Froning, and Janky, 1971). As skin content increased in relation to muscle and bone, fat increased and moisture and protein decreased. Skin collagen (connective tissue) did not pass through the screen but was expressed with the bone residue. Reduction of fat and increases in protein were obtained by hand trimming broiler necks and backs prior to deboning (Goodwin et al., 1968). The amino acid composition of MDTM has been shown to be comparable to hand boned turkey meat (Essary and

Ritchey, 1968). Bone composition of poultry was reported by Field et al. (1974).

Grunden, MacNeil, and Dimick (1972) reported the chemical and physical characteristics of MDPM obtained from various sources. Proximate composition varied considerably with source of material deboned. Composition of deboned turkey racks ranged as follows: moisture, 63.4% to 73.7%; fat, 12.7% to 22.5%; protein, 11.7% to 12.8%. pH values for MDTM were 6.4. Gardner color values ranged as follows: L, 43.1 to 47.0; a_L, 14.1 to 19.1; b_L, 11.5 to 11.8.

The mechanical deboning process exposes meat to considerable stress producing the characteristic paste-like nature of the product. Schnell et al. (1974) reported change in the ultrastructure of mechanically deboned meat. Vadehra and Baker (1970b) reported reduced cook loss for MDPM compared to hand boned meat and attributed this to the spongy nature of the product. Histologically, no muscle fibers were observed in several samples.

Storage stability problems of MDPM exist throughout the industry (Dawson, 1975). Major flavor changes occur during storage due to rapid lipid oxidation. Bone marrow constituents consisting of heme (Froning and Johnson, 1973) and lipid components (Moerck and Ball, 1973; Mello et al., 1976) become incorporated into mechanically deboned meat. Bone marrow accounts in part for higher fat contents of MDPM compared to hand boned meat. Moerck and Ball (1973) reported lipid composition of mechanically deboned chicken

as: triglycerides, 94.5% containing primarily 16:0, 18:1, 18:2, and 18:3 fatty acids; and phospholipids, 1.7% with high percentages of 20:3 to 20:6 unsaturated fatty acids.

Moerck and Ball (1974) performed TBA and fatty acid analyses on MDPM held at 4°C up to 15 days. Hexaenoic, pentaenoic, tetraenoic, and trienoic fatty acids of the phospholipid fraction were the major substrates of autoxidation. Autoxidation was minimized by the use of a commercial antioxidant (Tenox 2).

Lee et al. (1975) reported polyunsaturated fatty acid:heme molar ratios of 480:1 for mechanically deboned chicken meat, and suggested that linoleic acid:heme ratios of 500:1 exhibited maximum prooxidative activity. Antioxidant activity was shown for ratios below 89:1.

Janky and Froning (1973) investigated the heat denaturation of turkey meat myoglobin. Denaturation increased as pH decreased, and decreased by the addition of phosphate.

Janky and Froning (1975) reported a study designed to determine the oxidation rates of both heme proteins and lipids in MDTM. Oxidation rates were determined over a wide range of storage temperatures (30°C to -10°C). Heme oxidation was determined by measuring reflectance spectra; lipid oxidation was monitored by TBA analyses. Interactions between heme and lipid oxidations were noted between 10°C and 15°C (normal operating range of deboning processes). This indicated a catalytic effect of heme on

lipid oxidation. Hydroperoxides produced during lipid oxidation further accelerated heme protein oxidation.

Froning and Johnson (1973) reported a method of centrifugation to reduce lipid and heme levels of MDPM. The centrifugation resulted in improving the product stability as measured by TBA reaction.

Maxon and Marion (1970) reported linear increases in TBA reaction for MDTM held at 4°C for seven days. Cholesterol and cholesterol esters, free fatty acids, phosphatidylinositol and phosphatidylserine, and sphingomyelin were essentially unchanged during storage periods. Differences were noted in the triglyceride, diglyceride, monoglyceride, phosphatidylethanolamine, phosphatidylcholine, and lysophosphatidylcholine fractions.

Froning et al. (1971) reported that MDTM with high TBA numbers produced unacceptable frankfurters when added at 15% and stored frozen for three months. However, if fresh MDTM was used, storage stability was similar to red meat frankfurters.

Cunningham and Mugler (1973) reported the stability of cooked chicken wieners during frozen storage. These same workers (1974) reported the processing sequence and product composition and stability of deboned fowl meat, and suggested that raw deboned meat could be stored at -15°C for at least two months without serious flavor changes.

Froning (1973) found that chilling fowl in a

polyphosphate solution prior to deboning produced significantly lower TBA numbers than that of controls for all storage periods at -29°C up to eight weeks. He postulated that polyphosphate protected meat during the deboning operation where increased stress, contact with metal, and elevated temperatures accelerated lipid oxidation.

Dimick, MacNeil, and Grunden (1972) using carbonyl and sensory analyses reported that MDPM remained stable up to six days at 3°C. After holding raw MDPM six days, large increases in the concentration of carbonyls occurred after cooking. In general, deboned turkey racks were least stable of all meat sources evaluated.

MacNeil, Dimick, and Mast (1973) reported that the use of a rosemary spice extract having natural antioxidant properties, BHA+citric acid, and polyphosphate in MDPM maintained lower TBA numbers compared to a control held at 3°C up to 13 days.

Johnson, Cunningham, and Bowers (1974) reported the effect of storage time and temperature on the quality of MDTM. Deboned meat was stored at temperatures ranging from -13°C to -32°C and evaluated by TBA reaction, cooking loss, color and sensory analyses during 14 weeks of storage. Storage time and temperature affected cook loss. In general, storage time but not storage temperature affected eating quality. Gardner color values were not different among storage times and temperatures. TBA numbers increased with time and temperature of storage.

Composition, Hunter Lab color, water holding and emulsifying capacities, and TBA reactions were evaluated for various mechanically deboned poultry products obtained from different deboning machines (Dhillon and Maurer, 1975b). MDPM was stored at -25°C and results indicated that the products were still acceptable up to six months.

Numerous studies have involved utilization and functional acceptability of further processed products containing deboned poultry meat (Acton, 1973; Maurer, 1973; Young and Lyon, 1973; Angel et al., 1974; Baker, Darfler, and Angel, 1974; Baker and Darfler, 1975; Dhillon and Maurer, 1975a,b,c).

Baker, Darfler, and Vadehra (1972) reported that Kena improved the stability of frankfurter emulsions incorporating MDPM. Fermented turkey sausage prepared with MDTM was also improved by addition of Kena (McMahon and Dawson, 1976a). McMahon and Dawson (1976b) reported the effects of salt and phosphates on water binding, water holding, and emulsifying capacity of MDTM. Addition of 0.5% phosphate to 3% sodium chloride increased the amount of the extractable protein.

Cooking and Binding of Poultry Meat

Chemical and physical changes occurring in meat and poultry muscle during cooking have been reviewed (Bratzler, 1971; Palmer and Bowers, 1972; Paul, 1972; Meyer, 1975).

Goodwin et al. (1962) evaluated end point temperatures

and rates of cooking on shear resistance of turkey breast and thigh meat. Optimum tenderness of breast was obtained at internal temperatures of 77°C to 88°C.

Marquess, Carlin, and Augustine (1963) reported effects of oven temperature and internal temperature on quality of roasted turkey rolls. Increased oven temperatures resulted in a linear decreased cook yield of light meat rolls. No differences were reported in dark meat rolls with oven temperature. Greater cook losses were obtained for dark meat than light meat loaves. Bowers, Goertz, and Fry (1965) reported that generally there was no difference in quality scores between braised and roasted turkey rolls.

Hoke, McGeary, and Kleve (1967) evaluated the eating quality of light and dark meat turkey rolls cooked to different internal temperatures. As temperature increased, cook yield and juiciness decreased.

Wilkinson and Dawson (1967) reported shear values of cooked turkey rolls prepared from dark meat were greater than those prepared from light meat. Shear values decreased as internal temperature of dark meat rolls increased. Light meat rolls were most tender when cooked to an internal temperature of 77°C.

MacNeil and Dimick (1970a) evaluated the compositional changes during the cooking of turkey roasts. Cooking losses were greater in thigh meat roasts than in breast meat roasts.

Helmke and Froning (1971) reported the effect of end point cooking temperature and storage on the color of turkey meat. Gardner L values (lightness) increased and a_L values (redness) decreased with increased end point cooking temperatures.

Johnson and Bowers (1974a) studied cooking losses and sensory characteristics of precooked and freshly cooked turkey breast meat. Freshly cooked meat had the lowest cooking loss. Phosphate treatments improved cook yield.

Shults and Wierbicki (1973) reported that the use of various polyphosphates reduced the loss of natural juices during cooking. Greater decreases in cook loss were found when polyphosphates were used in combination with sodium chloride.

Emulsifying and binding characteristics have been shown to be the most important functional properties of poultry meat (Cunningham and Froning, 1972). In a review of factors affecting emulsifying characteristics these authors emphasized meat type, pH, protein solubility, and processing techniques.

Froning (1966) reported the use of polyphosphates (Kena) as a binder in ground chicken meat. Phosphates increased meat binding and tended to darken the color of the meat. Products were acceptable at 0.5% and 1.0% phosphate and unacceptable at 2.0%.

Froning (1965) stated that soaking fowl carcasses in 6% Kena resulted in increased binding and decreased cook

loss of loaves. Vadehra, Schnell, and Baker (1970) studied binding of salt extracted chicken meat and reported that cooking temperature was found to have an important influence on binding strength. Binding was superior when meat was heated for long periods at low temperatures. Optimum binding was found at 65°C and 75°C for 40 to 50 minutes.

Acton (1972) found that binding strength of poultry meat loaves increased as end point cooking temperature increased to 82°C.

Vadehra and Baker (1970a) stated that the binding mechanism involved in poultry meat was heat initiated. Maesso et al. (1970) reported that sodium chloride, Kena, and hexametaphosphate were found to enhance binding of poultry loaves. Kena and sodium chloride showed additive effects. Mechanical beating of the meat mixtures resulted in release of intracellular components and of increased binding strength. Decreased binding was noted with repeated freezing and thawing cycles; however, single freezing treatments did not affect the binding strength. Drip fluid was shown to possess binding properties.

Maesso, Baker, and Vadehra (1970) evaluated the use of vacuum pressure, pH, and different meat types on the binding characteristics of poultry meat. These workers reported increasing the pH from 5.0 to 8.0 greatly increased the binding tensile strength of loaves. Treatment under vacuum and cooking under pressure both

increased tensile strength of loaves.

Wardlow, McCaskill, and Acton (1973) studied the effect of postmortem muscle changes on characteristics of poultry meat loaves and stated that no industrial advantage appeared to exist for the use of pre-rigor meat.

MATERIALS AND METHODS

Source of Meat

Fresh turkey meat was obtained from a Michigan processing plant. Mechanically deboned turkey meat (MDTM) was processed through a Beehive Model AU968MF mechanical deboning machine (Beehive Machinery, Inc., Sandy, Utah). MDTM designated "light" was processed from hand boned breast racks. All other MDTM including that specified as "dark" was obtained from whole carcasses consisting of backs and skin. All MDTM was obtained in 40 pound boxes with polyethylene bag liners and transported to the laboratory in insulated boxes with a minimum delay (two to three hours). At no time did the temperature of the meat exceed 7°C.

Breast meat was commercially hand boned and consisted of the entire breast portion.

Meat used in the tocopherol supplementation study was obtained from turkeys raised and slaughtered under controlled conditions of the facilities at the Poultry Science Department, Michigan State University.

Analytical Methods

Sample Preparation. All meat items and formulated loaves were passed twice through a meat grinder fitted with

a 5 mm hole plate (The Hobart Mgf. Co., Troy, Ohio) prior to compositional analyses. Sample sizes normally ranging between 500 g and 1000 g were randomly obtained prior to grinding and hand mixed after grinding to obtain a uniform representative composite for compositional analyses. Sample preparation and handling procedures for TBA analysis were performed to minimize oxidation and are outlined with that method.

Moisture. The A.O.A.C. (1975, 25.003b) procedure for determining moisture was used for all meat items and loaves throughout all experiments. Triplicate 5 g samples were weighed into tared aluminum pans and dried to a constant weight at 100°C (18 hours) in a forced air oven. Moisture was expressed as percent weight lost during drying. The following equation was used:

$$\% \text{ moisture} = \frac{\text{weight of moisture lost (g)}}{\text{weight of initial sample (g)}} \times 100$$

Fat. Solids obtained from moisture determinations were used for Goldfisch ether fat extraction (A.O.A.C., 1975, 24.005b). Samples were continuously extracted for three and one-half hours using anhydrous ethyl ether. Ether was evaporated and the lipid extract dried at 100°C 30 minutes. The weight of the cooled extracted material was used to calculate total fat on a fresh weight basis using the following equation:

$$\% \text{ fat} = \frac{\text{weight of dried extract (g)}}{\text{weight of initial sample (g)}} \times 100$$

Protein. Protein was determined using a modified A.O.A.C. (1975, 23.009) semi-micro Kjeldahl procedure. Triplicate 0.5 g meat samples were digested by heating with 1 g sodium sulfate, 7 ml concentrated sulfuric acid, and 1 ml of a 10% w/v copper sulfate solution. Flasks were periodically turned during heating to obtain a completely clear pale green digestion. The digested sample was neutralized with sodium hydroxide, steam distilled, and a 30 ml distillate collected in a beaker containing 10 ml 2% w/v boric acid. Distillates were back titrated with standardized 0.1N sulfuric acid to a colorless brom cresol green end point. Percent protein was calculated on a fresh weight basis using the following equation:

$$\% \text{ protein} = \frac{(\text{net ml } H_2SO_4)(\text{N } H_2SO_4)(0.014)(6.25)}{\text{weight of initial sample (g)}} \times 100$$

Ash. Total ash was determined using a variation of the A.O.A.C. (1975, 29.012) method. Triplicate 5 g samples of fresh meat were weighed into previously ashed and tared Coors 50 ml (size 2) porcelain crucibles and dried at 100°C for 18 hours. Dried samples were pre-ashed over a Fisher burner. Crucibles were then placed in a muffle furnace and heated at 525°C until a uniform white ash was obtained (ca. 24 hours). Ashed crucibles were held in a desiccator until cool before weighing. Percent ash was calculated as

a function of the uncombustible material on a fresh weight basis using the following equation:

$$\% \text{ ash} = \frac{\text{weight of ash residue (g)}}{\text{weight of initial sample (g)}} \times 100$$

Calcium by EDTA. A volumetric EDTA method (Steagall, 1966) was used to determine total calcium of all meat items and loaves. Triplicate 10 g samples were digested with 15 ml hydrochloric acid and 15 ml deionized distilled water by boiling for 30 minutes in a 250 ml erlenmeyer flask, which was covered with a small watch glass. Additional deionized distilled water was added during digestion as necessary to maintain original volume. The samples were cooled, made to a 200 ml volume, and filtered through Whatman #1 filter paper. Duplicate 20 ml aliquots were taken from each filtrate and diluted with 50 ml deionized distilled water. The pH of each solution was adjusted to 12.5 with potassium hydroxide-potassium cyanide. Hydroxy naphthol blue calcium indicator (Mallinckrodt, No. 5630), ca. 200 mg to 300 mg, was added and the solution immediately titrated with 0.02 M EDTA (Mallinckrodt, St. Louis, Missouri) to a blue-green end point which persisted for one minute. Titer was 1 ml EDTA solution equivalent to 0.8 mg calcium. Calcium was expressed as a percent on a fresh weight basis using the following equation:

$$\% \text{ calcium} = \text{ml EDTA} \times 0.08$$

pH. The pH of meat was determined using a Corning (Model 10) pH meter, employing the expanded scale (Corning Scientific Instruments, Corning Glass Works, Corning, New York). Triplicate 25 g samples of meat were each blended with 25 ml deionized distilled water for two minutes in a VirTis macrohomogenizer, Model 23 (The VirTis Co., Gardiner, New York). pH readings were made by inserting the pH electrode directly into the homogenate.

Mineral Composition by Ash Analysis. Phosphorous, sodium, calcium, magnesium, manganese, iron, copper, and zinc were determined using an Applied Research Laboratory Quantograph (Applied Research Laboratory, Division of Bausch and Lomb, Glendale, California). The ash obtained from 5 g of fresh meat was dissolved in 15 ml nitric acid containing an internal standard and analyzed under standard conditions.

Using a standard curve, minerals were quantified by their characteristic emission spectra at specific wavelengths. Samples were run in triplicate and were expressed as either percent or parts per million (ppm) on a fresh weight basis.

Lipid Oxidation. 2-Thiobarbituric acid (TBA) analysis was carried out according to the procedure of Tarladgis et al. (1960). To reduce excessive handling and oxidation, products were sampled according to their specific requirements. Mechanically deboned meat, packaged in foil pans, was

sampled by taking plugs using a power boring machine equipped with a #10 cork boring bit. Mechanically deboned meat, packaged directly in polyethylene Mylar laminated pouches, was sampled using a spatula. Loaves were sampled by slicing and grinding through a quarter inch plate immediately preceding analysis. Random 10 g samples were homogenized in a VirTis macrohomogenizer Model 23 (285 ml flask) with 50 ml distilled water for two minutes. Homogenates were transferred with 47.5 ml distilled water to 500 ml boiling flasks and acidified with 2.5 ml hydrochloric acid:distilled water (1:2, v/v). Antifoam A spray (Dow Corning, Midland, Michigan) was used to prevent excessive foaming. Distillations were performed using a 300 mm Vigreux column attached to a 470 mm Leibig condenser with a 75° elbow. Distillates of 50 ml each were collected from four distillations per sample after distilling for 10 to fifteen minutes. Care was taken to maintain uniform heating times among distillations. TBA reagent (0.02M 2-thiobarbituric acid in 90% acetic acid) was prepared by dissolving 1.4416 g thiobarbituric acid (Eastman Organic Chemicals, Rochester, New York) with 50 ml distilled water and making to 500 ml volume with glacial acetic acid. An ultrasonic cleaner (Mettler Electronics Corp., Anaheim, California) was used to aid in the dissolving of the TBA reagent. TBA reactive substances were removed from acetic acid by refluxing ca. 2 g TBA/l acetic acid for three hours prior to redistillation.

Five ml of sample distillate were reacted with 5 ml TBA reagent in capped culture tubes (200 mm X 25 mm) for 35 minutes in a boiling water bath and cooled in cold tap water for 10 minutes prior to spectrophotometric quantitation (Beckman DB Spectrophotometer, Beckman Instruments, Inc., Fullerton, California). Duplicate reactions were run for each distillate. Absorbance was read against a reagent blank at 532 nm. Reagent blanks were consistently that of distilled water. TBA number (mg malonaldehyde/ 1000 g sample) was calculated using a constant of 7.8.

MDTM Substituted Loaf Study

Physical characteristics (composition, cooking characteristics, surface color and texture) and storage stability of turkey loaves formulated with various levels of MDTM were studied. TBA and sensory analyses were made on raw and precooked foil wrapped loaves held at $4^{o}C$ one week. Raw loaves were also evaluated after cooking. Additional raw and precooked loaves were stored foil wrapped and vacuum sealed at $-18^{o}C$ six months prior to analyses.

Preparation of Loaves. All loaves were formulated with breast meat and the appropriate amount of mechanically deboned meat. Treatment substitutions were prepared at 0%, 10%, 20%, 30%, and 100% MDTM. An additional treatment prepared from 70% MDTM and 30% rehydrated soy, designated 70%(30S), was included. Texturized soy (Response Chunks-3,

Central Soya, Chicago, Illinois) was rehydrated to three times its initial weight with distilled water prior to incorporation into MDTM.

Breast meat was cut by hand into approximately one inch cubes (2.5 cm) according to the following sequence: separation of pectoralis major and minor muscles, removal of excessive tendons, cutting into longitudinal strips, and crosscutting to obtain one inch cubes (2.5 cm).

Meat mixtures were prepared in batches of 10 kg for each treatment. Meat items were tumble mixed in a Leland Model 100A food mixer (Leland Detroit Mgf. Co., Detroit, Michigan) with 1.0% w/w reagent grade sodium chloride and 0.1% w/w Kena FP-28 (Calgon Corp., Pittsburg, Pennsylvania). Kena was added using 100 ml of a 10% w/v stock solution per 10 kg batch. Continuous paddle mixing was maintained at 4°C for 20 minutes under a covered flow of nitrogen. This batch size facilitated complete mixing. The meat mixture was sticky and cohesive following mixing due to extraction of the salt soluble proteins.

Kilogram loaves were formed by hand pressing the extracted meat mixture into 19 cm X 9 cm X 6 cm aluminum foil loaf pans. Pans were supported in a frame fashioned to stabilize the sides and ends during pressing. The meat mixture was added to the pan and pressed by hand with a flat surface. Although the force was not measured, attempts were made to maintain uniform pressure during all loaf pressings.

Packaging of Loaves. Loaves to be foil wrapped were covered with a single sheet of heavy duty aluminum foil and firmly pressed against the meat surface. They were sealed by crimping the foil to the edge of the loaf pan to prevent moisture loss during holding or storage.

Other loaves were vacuum sealed in polyethylene Mylar laminated pouches using a Kenfield Model C-14 vacuum sealer (International Kenfield Dist. Co., Parkridge, Illinois).

Cooking of Loaves. Loaves cooked prior to storage were designated as "precooked." Loaves cooked following raw storage were designated "raw, cooked." Loaves stored at -18°C were thawed by holding at 4°C overnight prior to cooking. All loaves were foil wrapped before cooking, placed on individual baking pans, and cooked in an Etco convection oven (Model 186.C2, Market Forge Co., Everett, Massachusetts) preset to 177°C±1°C and controlled by a Honeywell Versatronik controller (Model R7161B, Honeywell, Apparatus Controls Division, Minneapolis, Minnesota).

Center loaf temperatures were monitored using iron-constantan thermocouples and a Honeywell Electronik 16 recorder (Model #16303866). Based on preliminary trials, all loaves were cooked for 55 minutes to an internal temperature of about 75°C.

Percent Volatile Loss. Loaves were placed on tared baking pans for cooking. The total weight of each loaf and its pan was recorded prior to and after cooking.

Percent volatile loss was determined from the total weight loss during cooking and expressed as a function of initial meat weight using the following equation:

$$\% \text{ volatile loss} = \frac{\text{weight loss (g)}}{\text{fill weight (g)}} \times 100$$

Percent Meat Yield. Cooked meat loaves were removed from their foil pans and placed across the pans' upper edge at 90° and drained for two minutes. Broth drippings were retained on the tared baking pan. Loaf weight was obtained by direct weighing and expressed as a percent of the initial fill weight using the following equation:

$$\% \text{ meat yield} = \frac{\text{drained loaf weight (g)}}{\text{fill weight (g)}} \times 100$$

Percent Broth. Broth weight was obtained by weighing the liquid contained in the loaf pan and that collected in the baking pan. Broth weight was obtained by subtracting the tare weights of both the loaf pan and the baking pan. Broth was expressed as a percent of the initial fill weight using the following equation:

$$\% \text{ broth} = \frac{\text{broth weight (g)}}{\text{fill weight (g)}} \times 100$$

Dimensions and Volume of Loaves. The outer dimensions of meat loaves were determined using a plexiglass jig. Maximum length, width, and height dimensions were determined by aligning the loaf in the appropriate plane against the

fixed origin of the jig. Linear dimensions were obtained by displacement of a sliding end which was pressed against the surface of the loaf. Loaf dimensions were read directly in centimeters from an attached ruler. This procedure was used to obtain consistent measurement of the maximum dimension in any plane regardless of the shape of the loaf.

Loaf volume was determined by displacement in water. Loaves were wrapped in heat shrinkable film using a forced hot air sealer. A tight wrap devoid of wrinkles, excess film, and air pockets was obtained. Sealed loaves were individually placed in a basket previously equilibrated in a 5000 ml graduated cylinder containing 3000 ml distilled water. Basket and loaf were submerged and loaf volume was expressed as cubic centimeters of water displaced.

Slicing of Loaves. Cooked and cooled loaves were sliced into 2.5 cm slices using a plexiglass "slicing box." Each loaf was placed in the slicing box and uniform cross-cut slices made using a thin bladed bread knife. This procedure yielded slices of uniform thickness possessing a smooth clean cut surface. Five slices were obtained from the interior of each loaf; end cuts were not included in further analyses. After slicing, the entire loaf (slices in register) was placed in a new loaf pan and immediately evaluated for surface color and texture.

Surface Color of Cooked Crosscut Slices. The surface color of cooked crosscut slices was evaluated using both a Hunter Lab Model D-25 Color and Color Difference Meter (Hunter Associates Laboratory, Fairfax, Virginia) and an Agtron Model M-500-A Reflectance Spectrophotometer (Magnison Engineers, Inc., Instrument Division, San Jose, California). Hunter L, a_L, b_L, and ΔE were obtained for each slice using a white standard: L=93.0, a_L=-0.6, b_L=-0.1. Agtron reflectance was obtained at 436 nm (blue), 546 nm (green), 585 nm (yellow), and 640 nm (red) using full scale standardization. Sample handling as described below was similar for each instrument.

Five slices from each of two replicate loaves were evaluated per treatment. Two readings were made at 90° per slice to average any deviation due to irregular surface refractions. Slices were consistently measured in sequence within a loaf such that no two surfaces evaluated were adjacent to the same cut. Loaves and treatments were otherwise randomized.

Texture of Cooked Crosscut Slices. Binding and shear characteristics of cooked crosscut slices were evaluated using an Instron Universal Testing Instrument (Model TTBM, Instron Corp., Canton, Massachusetts). Breaking was performed using a modification of the apparatus described by Pepper and Schmidt (1975). The breaking bar was 1.9 cm in diameter and the support gap adjusted to 5.1 cm. Slices

were centered across this gap and broken as shown in Plate 1.

Plate 1. Breaking of Cooked Crosscut Slices Using Breaking Apparatus and Instron Universal Testing Instrument

Cross head travel was standardized at 5 cm referenced to the top of the support and the break cycle programmed to stop and return. Total area under the breaking curve was recorded on a digital integrator. Chart speed was 5 cm/min.

and cross head speed, 2 cm/min. Slice breaking was expressed as total work, a function of the area under the breaking curve, rather than peak force because of the complex nature of forces involved in meat binding. Breaking work was determined using the following conditions and calculated using the following equation:

$$\text{break work (kg-cm)} = \frac{(S)(C)(A)(V_x)}{500}$$

where S = selector setting (full scale load), 5

C = calibration setting at S=1, 1 kg/10 chart divisions

A = area units on integrator, divisions/min.

V_x = cross head speed, 2 cm/min.

Shear resistance was performed using a standard single blade shear cell. Cooked crosscut slices were positioned flat in the cell such that shearing occurred in the unbroken portion approximately 1 cm from the edge parallel to the center break line. Slices were reversed 180° to the opposite edge to obtain two shears per slice. Cross head rate and distance program and chart speed were the same as that used for slice breaking. Cross head reference was the bottom of the shear cell.

Total resistance to shear was calculated as:

$$\text{peak force (kg)} = (F_c)(S)(C)$$

where F_c = peak force on chart, chart divisions

S = selector setting, 20

C = calibration setting at S=1, 1 kg/10 chart divisions

Shear work was calculated as shown for break work.

Sensory Evaluation. Panelists were randomly chosen from students and faculty and staff of the Department of Food Science and Human Nutrition. Cooked meat samples were coded with two digit random numbers and evaluated under white light in segregated panel booths. Positional and psychological biases were minimized according to Amerine, Pangborn, and Roessler (1965). The flavor of loaves formulated with 0%, 10%, 20%, 30%, and 70%(30S) MDTM held raw and precooked at 4°C one week was evaluated using a seven point hedonic scale (1=dislike very much, 7=like very much). The degree of flavor difference of these loaves from the 0% MDTM reference was evaluated using a five point scale (1=no difference, 5=extreme difference). Acceptance was noted as either acceptable or not acceptable.

Raw and precooked foil wrapped and vacuum sealed loaves formulated with 0%, 20%, and 30% MDTM stored at -18°C six months were evaluated for appearance, flavor, texture, moistness, and general acceptability using seven point hedonic scales (appearance, flavor, and acceptability, 1=dislike very much, 7=like very much; texture, 1=very soft, 7=very firm; moisture, 1=very moist, 7=very dry). Triangle difference tests for 10% MDTM loaves stored under these conditions were used to independently evaluate

cooking and packaging treatments. Panelists were presented three samples of which two were identical and asked to indicate the odd sample.

In Vivo Tocopherol Supplementation Study

Tocopherol was supplemented in vivo through diet and subcutaneous injection. Meat was evaluated by the TBA test. Samples of breast meat, thigh meat, and MDTM were held at 4°C up to six days and stored at -18°C up to three months. Loaves formulated from breast meat and MDTM were foil wrapped and vacuum sealed and held at 4°C one week and stored at -18°C up to six months. Stored loaves were also evaluated after cooking.

Tocopherol Supplementation. Day old sexed large white turkey poults were obtained from a Michigan commercial hatchery, wing banded, and raised under controlled conditions at the Michigan State University Poultry Science Research and Teaching Center. Forty birds (20 female and 20 male) were brooded and raised to 12 weeks in a single floor pen. Feed management consisted of MSU Turkey Starter TS-75 (0 through 8 weeks) and MSU Turkey Grower TG-75 (8 weeks through slaughter). Birds were treated with Tylan (Eli Lilly and Co., Indianapolis, Indiana) during weeks 1, 4, 8, and 12 by addition to drinking water.

At 12 weeks of age male and female birds were individually blocked into groups of three by descending weight. Tocopherol supplementation treatments designated

control, diet, and inject were randomly assigned to birds within each weight grouping. This procedure was used to normalize weight distributions among treatments. Treatments were randomly assigned to three floor pens located side by side in the same house. Birds were segregated into assigned tocopherol supplementation treatments which were administered beginning the 12th week as follows:

control--no tocopherol supplementation

diet--feed supplemented 100 I.U. Vitamin E/kg above basal ration using 275 I.U./g alpha tocopheryl acetate premix

inject--biweekly subcutaneous injections on the back of the neck of 100 I.U. Vitamin E, administered as 50% alpha tocopheryl acetate in soy bean oil; last injection 72 hours prior to slaughter

Females were slaughtered at 18 weeks of age; males, at 20 weeks.

Slaughter and Further Processing. Slaughtering was randomly performed under controlled conditions which simulated commercial techniques. Birds were hung by feet, electronically stunned, bled, scalded in 59°C water, and defeathered in a mechanical picking machine. Birds were uniformly eviscerated and dressed. Dressed weights of individual birds were obtained. Dressed birds were held in crushed ice in a cold room overnight. Birds within each tocopherol treatment were pooled for further processing. Wings and drums were removed and not used in further

evaluations. Breast and thigh meat was obtained by hand boning in a commercial manner.

Meat samples were cut into 2.5 cm cubes and 200 g packaged into polyethylene bags for each TBA analysis period.

Hand boned whole carcasses from each lot were weighed, cut into 2.5 cm longitudinal strips using a meat band saw. Strips were mechanically deboned with a Bibun Type SCX13 deboning machine equipped with a sieve hole diameter of 5 mm (Bibun Co., Fukuyana Hiroshima, Japan). Deboning yields were calculated from carcass and MDTM weights. MDTM was packaged similarly to breast and thigh meats.

Loaves containing breast meat and MDTM substituted at 25% by weight were prepared and handled using procedures described for the MDTM Substituted Loaf Study.

MDTM Stability Study

Stability of MDTM treated with Type I, Type II, and Type III antioxidants was evaluated by the TBA test in a series of experiments.

Experiment I consisted of MDTM treated with EDTA at 50 ppm, 75 ppm, 100 ppm; with Tenox 2; and the accompanying interactions of Tenox 2 and EDTA. Samples were held at 4°C one through three days and stored at -18°C up to 12 months. Evaluation at 4°C of control MDTM, EDTA 75 ppm, Tenox 2, and Tenox 2+EDTA 75 ppm was continued through nine days.

Experiment II consisted of "light" and "dark" MDTM treated with various types and concentrations of antioxidants. Raw samples were held at 4°C one week and stored at -18°C three and six months prior to analyses. Stored samples were cooked and evaluated. These cooked samples were then held one week at 4°C and evaluated again. Prooxidant activity of reagent grade sodium chloride was also evaluated throughout this experiment.

Experiment III consisted of MDTM which was handled under different mixing stresses, subsequently packaged without air evacuation and as vacuum sealed, and held at 4°C one through six days. TBA and Hunter Lab color analyses were performed on all samples.

Treatments. The following treatments were directly incorporated into the MDTM:

Type I Antioxidants: Free Radical Terminators

(1) butylated hydroxyanisole (BHA); Eastman Chemical Products, Inc., Kingsport, Tennessee; prepared as 40% w/v in propylene glycol and delivered at 0.03% on a fat basis with a calibrated syringe

(2) Tenox A (BHA, 40%; anhydrous citric acid, 8%; propylene glycol, 52%); Eastman Chemical Products, Inc., Kingsport, Tennessee; delivered directly at 0.03% on a fat basis with a calibrated syringe

(3) Tenox 2 (BHA, 20%; propyl gallate, 6%; citric acid, 4%; propylene glycol, 70%); Eastman Chemical Products, Inc., Kingsport, Tennessee; delivered directly at 0.03% on a fat basis with a calibrated syringe

(4) D-alpha tocopherol (50% in soy bean oil carrier); Sigma Chemical Co., St. Louis,

Missouri; diluted 1:5 with propylene glycol and delivered with a calibrated syringe to obtain 100 ppm tocopherol based on fresh meat

Type II Antioxidants: Metal Chelators

(1) L (+) ascorbic acid; Eastman Kodak Co., Rochester, New York; delivered at levels of 50 ppm, 75 ppm, and 100 ppm by transferring 5.0 ml, 7.5 ml, and 10.0 ml respectively of a 10% w/v stock solution into 1000 g MDTM; all treatments were adjusted to 10 ml added liquid with distilled water

(2) citric acid (anhydrous); Sigma Chemical Co., St. Louis, Missouri; delivered at levels of 50 ppm, 75 ppm, and 100 ppm by transferring 5.0 ml, 7.5 ml, and 10.0 ml respectively of a 10% w/v stock solution into 1000 g MDTM; all treatments were adjusted to 10 ml added liquid with distilled water

(3) ethylenediaminetetraacetic acid, disodium salt (EDTA); Mallinckrodt, St. Louis, Missouri; delivered at levels of 50 ppm, 75 ppm, and 100 ppm by transferring 5.0 ml, 7.5 ml, and 10.0 ml respectively of a 10% w/v stock solution into 1000 g MDTM; all treatments were adjusted to 10 ml added liquid with distilled water

(4) Kena® FP-28 (commercial blend of sodium tripoly- and hexametaphosphates); Calgon Corp., Pittsburgh, Pennsylvania; added directly to MDTM at levels of 0.25%, 0.5%, and 0.75% by weight

Type III Antioxidants: Environmental Factors

(1) nitrogen; MDTM mixed under a flow of nitrogen gas, adjusted to a back pressure of 25 psig

(2) carbon dioxide; MDTM mixed under a flow of carbon dioxide gas, adjusted to a back pressure of 25 psig

Prooxidant activity of sodium chloride, reagent grade, added directly to MDTM at levels of 0.5%, 1.0%, and 1.5% by weight

Incorporation of Treatments. All treatments incorporated directly into MDTM were mixed in a Hobart Kitchen Aid K5-A food mixer equipped with a cake paddle (The Hobart Mfg. Co., Troy, Ohio). The bowl was covered with a plexiglass lid fitted with tygon tubing to facilitate mixing under nitrogen (2 to 4 psig). Treatments were added either using a calibrated syringe (Becton-Dickinson & Co., Rutherford, New Jersey) or a volumetric pipet through a hole (ca. 0.5 cm diameter) located above the path of the paddle or by direct addition in solid form prior to mixing. The mixer was operated at speed 6 for two minutes in a 4°C cold room.

Packaging of MDTM. Replicate 100 g samples for Experiment I for each sampling period were packaged in polyethylene Whirl-Pak bags.

Experiment II samples were packaged as 400 g MDTM for each sampling period in aluminum foil loaf pans (15 cm X 9 cm X 5 cm) and vacuum sealed in polyethylene Mylar laminated pouches. Loaves were repackaged and vacuum sealed following cooking.

Replicate 100 g samples for Experiment III were packaged in polyethylene Mylar laminated pouches which were smoothed and flattened to a 15 cm X 15 cm square and sealed without air evacuation and as vacuum sealed.

Color of MDTM. Surface color of MDTM samples held in Experiment III were evaluated directly through the surface

of the flattened sealed pouch using a Hunter Lab Color and Color Difference Meter Model D-25 and following the procedure described in the MDTM Substituted Loaf Study. The packaging material was compensated for during instrument standardization.

Statistical Analysis

The "Statistical Package for the Social Sciences" (Nie et al., 1975) program for the CDC 6500 computer operated by Michigan State University Computer Laboratory was used to assist statistical analyses.

Multi-way analyses of variance were determined using "Anova" program. Mean squares were reported after rounding. Single classification analyses of variance, Tukey mean separations, and two-tailed t-statistic comparisons were determined using subprogram "one-way."

Tukey separations were indicated, such that like letters among treatments denoted no significant difference ($P \leq 0.05$). Significant f ratios and t statistics were indicated by asterisks: *, $P \leq 0.05$; **, $P \leq 0.01$.

All mean values are reported plus or minus one standard deviation.

Coefficient of Variation (CV) was calculated, and expressed the standard deviation as a percent of the mean (Little and Hills, 1972).

Significant differences in triangle difference tests were obtained using Table E in Amerine, Pangborn, and

Roessler (1965).

Least square regression equations and correlation coefficients were obtained on a Canon F-20P calculator. Significant correlations were determined according to Table Y in Rohlf and Sokal (1969).

RESULTS AND DISCUSSION

MDTM Substituted Loaf Study

Proximate Composition

The mean values for proximate composition of MDTM substituted turkey loaves and meat ingredients are outlined in Table 1. Statistical analyses of these data are expressed in Table 2. Data were analyzed to include ingredient meats and all loaf formulations. Further response analysis was applied to the 0% through 30% substituted levels.

The proximate composition of the soy substitution is included for general comparative purposes.

Moisture. The percent moisture of breast meat was higher than mechanically deboned meat. Moisture content of loaves decreased linearly with increased levels of MDTM substitution. Percent moisture of 0% MDTM was significantly higher than all other treatments. Ten percent was significantly higher than 30% MDTM. The moisture content of all loaves was approximately 1% higher than the predicted level based on ingredient blends. This increase was due to the addition of 100 ml of a 10% Kena stock solution during tumble mixing of each 10 kg batch.

Table 1. Proximate Composition of Turkey Loaves Formulated with MDTM[1]

Treatments % MDTM	Moisture %	Fat %	Protein %	Ash %	Ca^{++}	pH
0	73.6±.2	.36±.06	21.6± .5	2.07±.04	.040±.0	5.74±.01
10	73.2±.1	1.59±.23	22.9± .6	1.96±.03	.049±.0	5.77±.01
20	73.0±.1	2.80±.06	22.4± .6	2.06±.01	.072±.0	5.81±.00
30	72.6±.2	4.53±.46	21.7± .6	2.07±.01	.088±.0	5.86±.00
70(30S)	68.2±.3	8.92±.46	16.3± .4	2.74±.05	.104±.0	6.53±.02
MDTM	67.7±.2	15.74±.18	14.3±1.6	1.10±.01	.145±.0	6.25±.02
Breast	73.7±.0	.15±.00	22.9±1.1	1.12±.01	.024±.0	5.78±.02

[1]Mean values and standard deviations (n=3 replicate samples)

Table 2. Analysis of Variance of Proximate Composition of Turkey Loaves Formulated with MDTM

Source of Variation	df	Meat Component: Moisture %	Fat %	Protein %	Ash %	Ca^{++} %	pH
0% through Breast							
		Mean Squares					
Treatments	6	20.10**	96.16**	36.95**	1.031**	.005**	.28**
Residual	14	.04	.07	.72	.001	.000	.00
CV(%)		.28	5.44	4.18	1.69	.00	.00
		Tukey Separations					
0		cd	a	b	b		a
10		bc		b			ab
20		ab		b	b		b
30		a		b	b		
70(30S)				a			
MDTM				a	a		
Breast		d	a	b	a		ab
0% through 30%							
		Mean Squares					
MDTM	3	.60**	9.48**	1.13	.009**	.001**	.01**
Linear	1	1.76**	28.21**	.00	.002	.004**	.02**
Deviation	2	.01	.11	1.70*	.013**	.000**	.00
Quadratic	1	.00	.19	3.02*	.011	.000	.00
Deviation	1	.02	.04	.38	.015**	.000**	.00
Residual	8	.02	.07	.32	.001	.000	.00
CV(%)		.19	11.40	2.55	1.55	.00	.00
		Tukey Separations					
0				a	a		a
10		b		a			a
20		ab		a	a		
30		a		a	a		
		t Statistic					
0 vs 10		3.51**	5.74**	2.82*	4.7**	19.8**	3.0**
0 vs 20		5.92**	11.42**	1.78	.1	---	8.5**
0 vs 30		8.38**	19.50**	.29	.3	---	14.9**
10 vs 20		1.78	5.68**	1.04	4.6**	48.1**	5.5**
10 vs 30		4.88**	13.76**	2.53*	5.0**	82.0**	11.9**
20 vs 30		3.09*	8.08**	1.49	.4	---	---
0 vs 10, 20,30		7.02**	14.97**	2.00	1.9	77.4**	10.8**

Products containing soy were significantly lower in moisture than those containing breast meat.

Fat. The percent fat of breast meat was significantly lower than mechanically deboned meat. Significant increases in total fat are shown at each level of substitution and reflect the predicted blended percentages of meat ingredients. The response to level of MDTM was linear. The soy substitution, though lower than the prediction, was higher than meat substitutions.

Protein. The percent protein of breast meat was significantly higher than that of MDTM. Substituted loaves did not significantly differ from breast meat. A quadratic response trend was shown for MDTM substitution. Percent protein in soy substituted loaves was not significantly higher than the ingredient MDTM.

Ash. The percent total ash was not different between breast meat and MDTM. MDTM might be expected to contain higher ash due to bone and marrow minerals. All prepared loaves had significantly higher percent ash than meat ingredients due to the addition of 1.0% NaCl and 0.1% Kena. The 10% substituted level was significantly lower in ash than other meat formulations, resulting in a significant quadratic response to MDTM substitution. Soy substituted loaves were significantly higher in ash than all meat substituted loaves.

Calcium by EDTA. The percent EDTA calcium of breast meat was significantly lower than mechanically deboned meat. Percent calcium increased with increased MDTM, and all substituted loaves were significantly different from one another. The response to level of MDTM was significantly linear; however, due to small within variance of the method, it may be expressed as a quadratic response. Percent calcium of the soy substitution reflected the level of MDTM.

pH. The pH of breast meat was significantly lower than that of mechanically deboned meat. pH of tissue meat would be expected to be lower due to postmortem glycolytic changes. MDTM also incorporates bone marrow constituents which raise the pH (Fields, 1976). The pH response of substituted loaves was a linear increase with increased MDTM. Levels of 0% and 10% MDTM did not have significantly different pH values; levels of 20% and 30% were each significantly different from all other levels. The pH of the soy substitution was higher than all substituted loaves and meat ingredients.

Mineral Composition by Ash Analysis

The mean values for minerals analyzed are presented in Table 3. Statistical analyses of these data are presented in Table 4. Data were analyzed as described for the proximate composition.

Table 3. Mineral Composition of Turkey Loaves Formulated with MDTM[1]

Treatments % MDTM	P %	Na %	Ca %	Mg %	Mn ppm	Fe ppm	Cu ppm	Zn ppm
0	.28±.04	.42±.02	.02±.00	.03±.00	3.88± .46	10.83±2.66	1.89± .96	9.91±1.88
10	.26±.00	.43±.04	.04±.00	.03±.00	5.23± .59	11.12± .33	2.81± .65	10.89± .36
20	.27±.02	.42±.03	.04±.01	.03±.00	3.12±1.54	13.20±2.97	1.73± .60	8.40±2.21
30	.25±.00	.42±.03	.04±.01	.02±.00	1.27± .35	11.38±1.86	1.32±1.03	6.81± .76
70(30S)	.25±.01	.53±.03	.12±.00	.04±.00	3.26± .08	26.39±3.14	2.66±1.27	7.79±1.14
MDTM	.22±.00	.09±.01	.13±.00	.18±.01	1.55± .78	20.57±1.74	1.71± .31	10.69± .94
Breast	.26±.01	.09±.01	.02±.10	.03±.00	2.91±1.88	12.81± .95	1.40±1.69	4.72±2.49

[1]Mean values and standard deviations (n=3 replicate samples)

Table 4. Analysis of Variance of Mineral Composition of Turkey Loaves Formulated with MDTM

Source of Variation	df	Mineral P %	Na %	Ca %	Mg %	Mn ppm	Fe ppm	Cu ppm	Zn ppm
0% through Breast									
		Mean Squares							
Treatments	6	.001*	.093**	.006**	.000**	5.455**	107.028**	1.020	15.048**
Residual	14	.000	.001	.000	.000	1.035	4.761	1.051	2.511
CV(%)		.00	9.19	.00	.00	33.57	14.37	53.12	18.74
0		b	b	ab	b	ab	a	a	b
10		ab	b	ab	b	b	a	a	b
20		ab	b	ab	b	ab	a	a	ab
30		ab	b	b	ab	a	a	a	ab
70(30S)		ab		c		ab	b	a	ab
MDTM		a	a	c	a	a	b	a	b
Breast		ab	a	a	b	ab	a	a	a

Table 4. (cont'd.)

Source of Variation	df	Mineral P %	Na %	Ca %	Mg %	Mn ppm	Fe ppm	Cu ppm	Zn ppm
0% through 30%									
						Mean Squares			
MDTM	3	.000	.000	.000	.000	8.195**	3.439	1.196	9.546*
Linear	1	.001	.000	.000*	.000*	14.850*	2.105	1.176	20.803*
Deviation	2	.000	.000	.000	.000	4.868*	4.106	1.207	3.917
Quadratic	1	.000	.000	.000	.000	7.664*	3.328	1.320	4.979
Deviation	1	.000	.000	.000	.000	2.172	4.885	1.094	2.855
Residual	8	.000	.001	.000	.000	.772	4.862	.695	2.289
CV(%)		.00	7.47	.00	.00	26.05	18.96	43.03	16.81
						Tukey Separations			
0		a	a	a	a	b	a	a	ab
10		a	a	a	a	b	a	a	b
20		a	a	a	a	ab	a	a	ab
30		a	a	a	a	a	a	a	a
						t Statistic			
0 vs 10		.96	.39	2.19	1.70	1.88	.16	1.36	.80
0 vs 20		.89	.01	2.08	1.98	1.06	1.32	.24	1.22
0 vs 30		1.53	.16	2.59*	2.97*	3.64**	.31	.84	2.51*
10 vs 20		.07	.40	.10	.28	2.94*	1.16	1.60	2.01
10 vs 30		.56	.22	.41	1.27	5.52**	.15	2.19	3.30*
20 vs 30		.64	.18	.51	.99	2.58*	1.01	.59	1.29
0 vs 10, 20,30		1.38	.22	2.80*	2.71*	1.16	.73	.11	1.20

Phosphorous. The percent phosphorous did not significantly differ between breast meat and mechanically deboned meat. No increases in phosphorous were shown for loaves compared to meat ingredients as might have been anticipated due to the addition of 0.1% Kena. There were no significant differences between substituted meat loaves, and though there was a decreasing trend, there was no significant response to the level of substitution.

Sodium. The percent sodium of breast and deboned meat were equivalent. All loaves had significantly higher sodium content than the meat ingredients due to added sodium chloride during preparation. The sodium percent of substituted loaves was in the range anticipated by calculation from the formulation, such that 1.0% w/w sodium chloride approximated 0.4% w/w sodium. There were no significant differences in the sodium content among all meat substituted loaves. The soy substituted loaves had a significantly higher sodium content than meat substituted loaves.

Calcium. The percent calcium of mechanically deboned meat was significantly higher than that of breast meat. These levels were in the same range as determined by EDTA titration; however, the high standard deviation of the breast sample was noted. The calcium content of substituted loaves was considerably lower than reported by EDTA titration. No explanation for these differences was

offered. No significant differences were shown between substituted meat loaves 0% through 30%. Though there were no differences between substitution levels, the response was linear. The soy substitution resulted in significantly higher calcium content than meat substitutions.

Magnesium. Mechanically deboned meat had a significantly higher percent magnesium than breast meat. There was no significant difference or response due to substitution in loaves 0% through 30%. Soy substitution was not significantly different from meat substituted loaves. The relatively large difference between MDTM and breast meat did not manifest itself as a trend throughout MDTM loaf substitution, therefore, it could be suspect.

Manganese. Manganese differences between meats and loaves were relatively small. There was no significant difference between breast meat and mechanically deboned meat. Manganese content of substituted loaves was scattered, though there existed a decreasing linear and quadratic response to added MDTM substitution. Substitutions of 0% and 10% were significantly higher in manganese than the 30% substitution. The manganese levels of soy substituted loaves were similar to those containing breast meat. Since differences were small and no significant differences shown for ingredient meats, no conclusive statements were made.

Iron. The iron content of mechanically deboned meat was significantly higher than breast meat. This was as anticipated due to high iron content of bone marrow (Field, 1976). There were, however, no differences in iron content among MDTM substituted loaves. There was no significant response to the level of substitution and all meat loaves did not significantly differ from breast meat. The soy substitution possessed the greatest iron content, though not significantly different from mechanically deboned turkey meat.

Copper. No significant differences were shown for the copper content of meat ingredients or substituted loaves.

Zinc. The zinc content of MDTM was significantly greater than for breast meat. These data, however, are questionable because of significant linear decreases with increases in MDTM substitution. The error in measurement of breast meat was rather high to support a conclusion.

Changes Occurring during Cooking

Mean values for percent meat yield, percent volatile loss, and percent broth are presented in Table 5. Statistical analyses of these data are presented in Table 6. Loaves formulated with 100% MDTM and those substituted with soy were included in analyses for comparative purposes. Substitutions of 0% through 30%

Table 5. Changes Occurring during Cooking of Turkey Loaves Formulated with MDTM[1]

Treatments % MDTM	Meat Yield[2] %	Volatile Loss[3] %	Broth[4] %
0	76.4± .2	11.8± .9	10.5± .9
10	78.2± .1	8.5±1.8	11.8±1.6
20	80.9± .8	10.1± .1	8.0± .2
30	84.8± .5	7.4± .4	7.0± .9
70(30S)	84.6±2.0	11.1±1.7	1.5± .0
100	86.5± .0	7.2± .4	5.8± .4

[1]Mean values and standard deviations (n=2 loaves)

[2]$\frac{\text{Cooked Meat Weight}}{\text{Fill Weight}} \times 100$

[3]$\frac{\text{Weight Loss during Cooking}}{\text{Fill Weight}} \times 100$

[4]$\frac{\text{Broth Weight}}{\text{Fill Weight}} \times 100$

Table 6. Analysis of Variance of Changes Occurring during Cooking of Turkey Loaves Formulated with MDTM

Source of Variation	df	Loaf Measure: Meat Yield %	Volatile Loss %	Broth %
0% through 100%				
		Mean Squares		
MDTM	5	33.32**	7.77*	26.68**
Residual	6	.78	1.23	.73
CV(%)		1.08	11.87	11.51
		Tukey Separations		
0		a	b	bc
10		ab	ab	c
20		b	ab	ab
30		c	a	a
70(30S)		c	ab	
100		c	a	a
		t Statistic		
0 vs 100		10.88**	4.24**	5.56**
10 vs 100		8.95**	1.22	7.02**
20 vs 100		6.00**	2.66*	2.69*
30 vs 100		1.77	.18	1.40
0 vs 70(30S)		8.90**	.68	10.53**
10 vs 70(30S)		6.97**	2.34	11.99**
20 vs 70(30S)		4.02**	.90	7.67**
30 vs 70(30S)		.21	3.38*	6.38**
100 vs 70(30S)		1.98	3.56*	4.97**
0,10,20, 30 vs 70(30S)		6.22**	1.88	11.57**

Table 6. (cont'd.)

Source of Variation	df	Loaf Measure: Meat Yield %	Volatile Loss %	Broth %
0% through 30%				
		Mean Squares		
MDTM	3	27.37**	7.66*	9.68*
Linear	1	79.81**	14.16*	20.59*
Deviation	2	1.16	4.41	4.23
Quadratic	1	2.31*	.18	2.76
Deviation	1	.01	8.65*	5.70
Residual	4	.25	1.09	1.06
CV(%)		.62	11.04	11.38
		Tukey Separations		
0		a	b	ab
10		a	ab	b
20			ab	ab
30			a	a
		t Statistic		
0 vs 10		3.57*	3.20*	1.21
0 vs 20		9.03**	1.67	2.38
0 vs 30		16.87**	4.30*	3.44*
10 vs 20		5.46**	1.53	3.59*
10 vs 30		13.30**	1.10	4.65**
20 vs 30		7.84**	2.63	1.07
0 vs 10, 20,30		12.04**	3.75*	1.88

MDTM were also analyzed independently for response to treatment effects.

Percent meat yield increased significantly and exhibited a significant linear response to increased levels of MDTM. These increases of meat yield were parallelled by decreased percent broth. The volatile loss data fluctuated with MDTM substitution. Meat yield increases were probably due to greater water holding and fluid encapsulation. The higher pH of loaves substituted with MDTM may have raised water holding capacity of the protein. The physical structure of MDTM may have aided fluid retension by entrapping additional broth.

The method used to determine these cooking changes was by direct weighing to obtain values for each component. The meat yield determination was an independent measure without confounding aspects. However, if any overflow occurred during cooking it would necessarily confound the percent volatile loss and percent broth. Overflow would decrease the percent broth and greatly increase the percent volatile loss. Though excessive overflow did not occur in any treatment, even small amounts may have accounted for the scattered volatile loss data.

Volume Relationships of Cooked Loaves

Mean values for volume relationships of cooked turkey loaves are presented in Table 7. Statistical analyses of these data are presented in Table 8.

Table 7. Volume Relationships of Cooked Turkey Loaves Formulated with MDTM[1]

Treatments % MDTM	Volume cc	Loaf Dimensions (l X w X h) cm	Calculated Volume cc	Δ Volume[2] %	Apparent Density[3] g/cc
0	735±21	16.2±.4 X 8.5±.0 X 7.0±.0	967±21	31.6± .9	1.04±.02
10	737± 7	16.4±.1 X 8.6±.1 X 7.0±.0	990±12	34.7± .4	1.06±.01
20	785±21	16.6±.4 X 8.8±.1 X 7.2±.1	1054± 7	34.4±4.4	1.03±.03
30	820±28	16.9±.1 X 9.2±.1 X 7.2±.1	1121±12	36.8±6.1	1.03±.03
70(30S)	900± 0	17.3±.3 X 9.4±.1 X 7.6±.0	1242±11	38.0±1.2	.94±.02
100	850± 0	16.8±.1 X 9.1±.1 X 7.5±.1	1151±24	35.4±2.8	1.02±.00

[1]Mean values and standard deviations (n=2 loaves)

[2]$\frac{\text{Calculated Volume cc - Volume cc}}{\text{Volume cc}} \times 100$

[3]$\frac{\text{Loaf Weight}}{\text{Loaf Volume}}$

Table 8. Analysis of Variance of Volume Relationships of Cooked Turkey Loaves Formulated with MDTM.

Source of Variation	df	Loaf Measure: Volume cc	Loaf Dimensions (l X w X h) cm			Calculated Volume cc	Δ Volume %	Apparent Density g/cc
0% through 100%					Mean Squares			
MDTM	5	8588.3**	.30*	.25**	.14**	21706.5**	9.95	.004*
Residual	6	291.7	.06	.01	.01	243.8	11.34	.001
CV(%)		2.12	1.46	1.11	1.37	1.44	9.58	3.09
					Tukey Separations			
0		a	a	a	a	a	a	ab
10		a	a	ab	a	a	a	b
20		ab	a	bc	a		a	ab
30		b	a	cd	a	b	a	ab
70(30S)		c	a	d	b		a	a
100		bc	a	c	b	b	a	ab
					t Statistic			
0 vs 100		6.73**	2.04	7.35**	7.78**	11.78**	1.14	.69
10 vs 100		6.73**	1.63	5.51**	7.78**	10.30**	.20	1.55
20 vs 100		3.80**	.82	3.06*	4.95**	6.18**	.30	.39
30 vs 100		1.75	.61	.61	4.24**	1.90	.42	.56
0 vs 70(30S)		9.66**	4.29**	11.64**	---	17.64**	1.92	3.56*
10 vs 70(30S)		9.66**	3.88**	9.80**	---	16.16**	.99	4.43**
20 vs 70(30S)		6.73**	3.06*	7.35**	5.66**	12.04**	1.09	3.27*
30 vs 70(30S)		4.68**	1.63	3.67**	4.95**	7.77**	.36	3.43*
100 vs 70(30S)		---	2.24	4.29**	.71	5.87**	.79	2.87*
0,10,20, 30 vs 70(30S0		9.72**	4.07**	10.26**	8.72**	16.96**	1.38	4.65**

Table 8. (cont'd.)

Source of Variation	df	Loaf Measure: Volume cc	Loaf Dimensions (l X w X h) cm			Calculated Volume cc	Δ Volume %	Apparent Density g/cc
0% through 30%								
					Mean Squares			
MDTM	3	3445.8*	.16	.16**	.03	9615.0**	9.32	.000
Linear	1	9302.5**	.46*	.46**	.09**	27746.5**	23.84	.000
Deviation	2	517.5	.02	.00	.01	549.2	2.06	.000
Quadratic	1	612.5	.03	.01	.00	948.3	.24	.000
Deviation	1	422.5	.00	.00	.01	150.2	3.88	.001
Residual	4	437.5	.07	.00	.01	194.1	14.69	.001
CV(%)		.27	1.60	.00	1.40	10.46	11.15	3.04
					Tukey Separations			
0		a	a	a	a	a	a	a
10		a	a	ab	a	a	a	a
20		a	a	b	a		a	a
30		a	a		a		a	a
					t Statistic			
0 vs 10		.00	.38	2.45	---	1.66	.82	.75
0 vs 20		2.39	1.14	5.72**	2.53	6.28**	.73	.25
0 vs 30		4.06*	2.48	10.61**	3.16*	11.06**	1.37	.11
10 vs 20		2.39	.76	3.26*	2.53	4.62**	.08	1.00
10 vs 30		4.06*	2.09	8.16**	3.16*	9.40**	.55	.86
20 vs 30		1.67	1.34	4.89**	.63	4.79**	.64	.14
0 vs 10, 20,30		2.63	1.64	7.66**	2.32	7.76**	1.19	.16

The volume of loaves increased with increased levels of MDTM substitution. Though these differences were not highly significant among 0%, 10%, 20%, and 30%, the response trend was linear.

Increases in the overall maximum loaf dimensions of length, width, and height were indicative of the volume changes. A theoretical volume of each loaf was calculated as a rectangular solid from the maximum dimensions. The calculated volume was, therefore, much greater than the actual volume. The percent difference between the actual and the calculated volume (Δ volume percent) was determined as an indication of loaf distortion. Greater differences between these measures (increased Δ volume percent) indicated greater loaf distortion due to factors such as slanting sides, peaking tops or general changes which would result in greater divergence from the theoretical rectangular solid. The Δ volume percent increased with increased levels of meat substitution. Visual examination viewed the distortion to be primarily due to peaking tops. No substitution level appeared sufficiently distorted to be objectionable. The apparent density of loaves decreased with added deboned meat, though these changes were not significant in the 0% through 30% substitution range.

Soy loaves had the greatest volume and lowest density. The Δ volume percent was greater for soy loaves than for all other treatments.

Surface Color of Crosscut Slices

Visual Appearance. Visual appearance of crosscut slices from both raw and cooked MDTM substituted loaves may be seen in Plate 2. Note that chunks of breast meat are held in a matrix of MDTM as the level of MDTM increases from 0% to 30%.

Hunter Lab. Mean values of Hunter Lab analyses are presented in Table 9. Statistical analyses of these data are presented in Table 10. Analysis of surface color of cooked crosscut slices by Hunter Lab resulted in no differences between replicate loaves for all measures. The Hunter L value decreased significantly with increased levels of MDTM indicating increased darkening (a more intense gray surface color). Though 10% and 20% levels were not significantly different from each other, the overall response was linear. Soy substituted and 100% MDTM loaves had significantly lower L values when compared against meat substituted loaves. They, however, did not differ from each other.

Hunter a_L significantly increased with increased MDTM substitution indicating greater redness. The response was linear and significant differences were detected between the low substitution levels (0% and 10%) and the high substitution levels (20% and 30%), but not within each substitution level. Soy and 100% substitutions had significantly higher a_L values than meat substituted

Plate 2. Visual Appearance of Crosscut Slices from Raw and Cooked Loaves Substituted with MDTM from 0% through 30% Levels

Table 9. Surface Color of Cooked Turkey Loaf Crosscut Slices: Hunter Lab[1]

Treatments % MDTM	L	a_L	b_L	ΔE
0	65.6±1.5	1.0±.5	11.8±.4	30.2±1.0
10	63.5±1.5	1.5±.5	11.9±.3	31.9±1.4
20	62.4±1.0	2.2±.6	11.8±.3	32.9±1.0
30	59.1±1.8	2.9±.3	11.6±.2	36.0±1.7
70(30S)	51.7± .5	4.5±.6	11.6±.2	43.2± .5
100	51.6± .8	4.6±.3	11.0±.2	43.1± .8

[1]Mean values and standard deviations (5 slices/loaf X 2, n=10)

Table 10. Analysis of Variance of Surface Color of Cooked Turkey Loaf Crosscut Slices: Hunter Lab

Source of Variation	df	Hunter Lab Measure L	a_L	b_L	ΔE
0% through 100%					
		Mean Squares			
Main Effects	6	304.52**	19.12**	.78**	271.33**
MDTM	5	365.34**	22.84**	.94**	325.56**
Loaf	1	.47	.54	.00	.20
2-Way MDTM X Loaf	5	1.36	.14	.06	.94
Residual	48	1.66	.24	.08	1.34
CV(%)		2.18	17.49	2.44	3.20
MDTM	5	365.34**	22.84**	.93**	325.56**
Residual	54	1.60	.24	.07	1.28
		Tukey Separations			
0			a	a	
10		b	a	a	a
20		b	b	a	a
30			b	a	
70(30S)		a	c	a	b
100		a	c		b
		t Statistic			
0 vs 100		24.60**	16.51**	6.19**	25.60**
10 vs 100		20.96**	14.62**	6.94**	22.21**
20 vs 100		19.11**	11.04	6.28**	20.23**
30 vs 100		13.27**	8.14**	4.54**	14.14**
0 vs 70(30S)		24.42**	15.82**	1.16	25.78**
10 vs 70(30S)		20.79**	13.93**	1.90	22.39**
20 vs 70(30S)		18.94**	10.34**	1.24	20.40**
30 vs 70(30S)		13.09**	7.44**	.50	14.31**
100 vs 70(30S)		.18	.69	5.04**	.18
0,10,20, 30 vs 70(30S)		24.43**	15.04**	1.20	26.21**

Table 10. (cont'd.)

Source of Variation	df	Hunter Lab Measure L	a_L	b_L	ΔE
0% through 30%					
			Mean Squares		
Main Effects	4	54.00**	5.01**	.12	44.44**
MDTM	3	71.83**	6.58**	.15	59.21**
Loaf	1	.51	.32	.00	.11
2-Way					
MDTM X Loaf	3	1.88	.23	.07	1.25
Residual	32	2.24	.22	.10	1.77
CV(%)		2.39	24.56	2.69	4.06
MDTM	3	71.83**	6.58**	.15	59.21**
Linear	1	206.25**	19.47**	.23	169.08**
Deviation	2	4.63	.13	.11	4.28
Quadratic	1	3.91	.12	.23	4.66
Deviation	1	5.35	.14	.00	3.90
Residual	36	2.16	.23	.09	1.68
			Tukey Separations		
0			a	a	
10		a	a	a	a
20		a		a	a
30				a	
			t Statistic		
0 vs 10		3.14**	1.92	.66	2.96**
0 vs 20		4.73**	5.58**	.07	4.68**
0 vs 30		9.77**	8.53**	1.47	9.99**
10 vs 20		1.60	3.66**	.59	1.73
10 vs 30		6.64**	6.61**	2.14*	7.04**
20 vs 30		5.04**	2.95**	1.55	5.31**
0 vs 10, 20,30		7.20**	6.55**	.30	7.00**

loaves.

Substitution of 0% through 30% MDTM resulted in no significant differences or trends in Hunter b_L values, a measure of yellowness. Loaves substituted with 100% MDTM had significantly lower b_L values, though this difference was small.

Total color difference from the standard, ΔE, considers all scales and is the geometric sum of all differences from the initial standard. ΔE exhibited significant increasing linear response with increased MDTM substitution. The 10% and 20% levels were not significantly different from each other, though these were different from all others. Soy and 100% MDTM treatments, though not different from each other, had significantly greater ΔE values than loaves containing breast meat.

Agtron Reflectance. Agtron reflectance mean values for substituted treatments are presented in Table 11. Statistical analyses of these data are presented in Table 12. No significant differences were detected between replicate loaves for all wavelength reflectances. Reflectance values decreased in a significantly linear trend for all measured wavelengths as the level of MDTM substitution increased from 0% through 30%. Significant differences were not detected between 10% and 20% substitution levels for 436 nm (blue), 546 nm (green), and 640 nm (red); however, these levels were significantly different from all others. Significant differences in

Table 11. Surface Color of Cooked Turkey Loaf Crosscut Slices: Agtron Reflectance[1]

Treatments % MDTM	Wavelength 436nm	546nm	585nm	640nm
0	25.7±1.5	41.7±1.8	46.5±2.0	58.8±1.9
10	22.6±1.3	38.2±1.9	43.4±4.5	55.4±1.9
20	20.9±1.5	36.3±1.9	40.2±2.2	53.8±2.3
30	17.1±1.7	32.0±2.3	36.8±4.8	50.8±2.4
70(30S)	10.7± .5	23.0± .8	26.4± .7	39.9±1.0
100	10.4± .5	22.3±1.2	25.6±1.1	39.5±1.3

[1]Mean values and standard deviations (5 slices/loaf X 2, n=10)

Table 12. Analysis of Variance of Surface Color of Cooked Turkey Loaf Crosscut Slices: Agtron Reflectance

Source of Variation	df	Wavelength 436nm	546nm	585nm	640nm
0% through 100%			Mean Squares		
Main Effects	6	434.53**	543.23**	640.42**	555.71**
MDTM	5	401.32**	651.47**	764.42**	666.80**
Loaf	1	.60	2.02	20.42	.27
2-Way					
MDTM X Loaf	5	1.08	1.50	1.62	3.35
Residual	48	1.68	3.18	9.68	3.66
CV(%)		7.24	5.52	8.52	3.85
MDTM	5	401.32**	651.47**	764.42**	666.80**
Residual	54	1.61	3.00	9.13	3.57
			Tukey Separations		
0				d	
10			b	cd	b
20			b	bc	b
30				b	
70(30S)		a	a	a	a
100		a	a	a	a
			t Statistic		
0 vs 100		26.98**	25.05**	15.47	22.85**
10 vs 100		21.52**	20.53**	13.17**	18.83**
20 vs 100		18.52**	18.08**	10.81**	16.93**
30 vs 100		11.82**	12.53**	8.29**	13.38**
0 vs 70(30S)		26.46**	24.15**	14.88**	22.38**
10 vs 70(30S)		20.99**	19.63**	12.58**	18.35**
20 vs 70(30S)		17.99**	17.18**	10.21**	16.46**
30 vs 70(30S)		11.29**	11.62**	7.70**	12.91**
100 vs 70(30S)		.53	.90	.59	.47
0,10,20, 30 vs 70(30S)		24.26**	22.95**	14.35**	22.17**

Table 12. (cont'd.)

Source of Variation	df	Wavelength 436nm	546nm	585nm	640nm
0% through 30%					
		Mean Squares			
Main Effects	4	96.42**	122.62**	135.72**	83.40**
MDTM	3	128.49**	163.37**	173.96**	111.07**
Loaf	1	.22	.40	21.02	.40
2-Way					
MDTM X Loaf	3	1.76	2.07	1.29	3.87
Residual	32	2.40	4.22	14.16	4.91
CV(%)		7.18	5.54	9.02	4.05
MDTM	3	128.49**	163.37**	173.96**	111.07**
Linear	1	378.12**	480.50**	521.64**	327.68**
Deviation	2	3.68	4.80	.12	2.76
Quadratic	1	1.22	1.60	.22	.40
Deviation	1	6.12	8.00	.00	5.12
Residual	36	2.29	3.94	13.28	4.70
		Tukey Separations			
0				c	
10		a	a	bc	a
20		a	a	ab	a
30				a	
		t Statistic			
0 vs 10		4.58**	3.94**	1.90	3.51**
0 vs 20		7.10**	6.08**	3.87**	5.16**
0 vs 30		12.72**	10.93**	5.95**	8.25**
10 vs 20		2.51	2.14	1.96	1.65
10 vs 30		8.13**	6.98**	4.05**	4.74**
20 vs 30		5.62**	4.84**	2.09*	3.09**
0 vs 10, 20,30		9.96**	5.56**	4.78**	6.91**

reflectance at 585 (yellow) were shown among groupings of two substituted levels (0% and 10%, 10% and 20%, 20% and 30%). Soy and 100% MDTM substitutions, though not significantly different from each other, exhibited significantly lower reflectance values at all wavelengths when compared to meat substituted loaves.

Texture of Cooked Crosscut Slices

The mean values for texture evaluation measures are presented in Table 13. Statistical analyses of these data are summarized in Table 14.

There were no significant differences between replicate loaves for all texture evaluations. Breaking work was the total work required to break each slice and was indicative of the degree of binding between meat pieces in the formulated loaf. Decreased breaking work therefore indicated a reduction in binding strength. Breaking work decreased with a linear response to increased levels of MDTM substitution. No significant differences in breaking work were detected among the substitution levels 0% through 30%. All MDTM substituted meat loaves were not significantly different from 100% MDTM. Loaves containing soy had the lowest breaking work value.

Slice shearing, expressed as both work and total force, was evaluated as a measure of slice tenderness. The shearing process entailed cutting straight through the slice, thereby measuring slice tenderness independently

Table 13. Texture of Cooked Turkey Loaf Crosscut Slices: Instron Universal Instrument[1]

Treatments % MDTM	Breaking Work kg-cm	Shear Work kg-cm	Shear Force kg
0	.670±.11	3.22±.52	168.5±27.9
10	.603±.15	2.95±.15	151.9±23.2
20	.586±.14	2.69±.47	136.8±27.4
30	.553±.10	2.31±.34	113.5±22.6
70(30S)	.419±.10	1.58±.15	69.7± 9.5
100	.468±.11	1.60±.22	68.2± 6.3

[1]Mean values and standard deviations:
break (n=10, 1 break/slice X 5 slices/loaf X 2);
shear (n=20, 2 shears/slice X 5 slices/loaf X 2)

Table 14. Analysis of Variance of Texture of Cooked Turkey Loaf Crosscut Slices: Instron Universal Instrument

Source of Variation	Texture Measure: Breaking Work df	Breaking Work kg-cm	Shear Work df	Shear Work kg-cm	Shear Force kg
0% through 100%					
			Mean Squares		
Main Effects	6	.07**	6	7.98**	29673.4**
MDTM	5	.08**	5	9.57**	35544.1**
Loaf	1	.10	1	.03	320.1
2-Way					
MDTM X Loaf	5	.00	5	.15	203.5
Residual	48	.02	108	.16	464.6
CV(%)		25.71		16.67	18.25
MDTM	5	.08**	5	9.57**	35544.1**
Residual	54	.01	114	.16	451.8
		Tukey Separations			
0		c		c	c
10		bc		bc	bc
20		bc		b	b
30		abc			
70(30S)		a		a	a
100		ab		a	a
		t Statistic			
0 vs 100		3.79**		13.03**	14.92**
10 vs 100		2.53*		10.84**	12.45**
20 vs 100		2.20*		8.79**	10.20**
30 vs 100		1.59		5.71**	6.74**
0 vs 70(30S)		4.73**		13.20**	14.70**
10 vs 70(30S)		3.46**		11.02**	12.23**
20 vs 70(30S)		3.13**		8.97**	9.98**
30 vs 70(30S)		2.52*		5.89**	6.52**
100 vs 70(30S)		.93		.17	.22
0,10,20, 30 vs 70(30S)		4.38**		12.36**	13.73**

Table 14. (cont'd.)

Source of Variation	Texture Measure: Breaking Work df	Breaking Work kg-cm	Shear Work df	Shear Work kg-cm	Shear Force kg
0% through 30%					
			Mean Squares		
Main Effects	4	.02	4	2.29**	8306.2**
MDTM	3	.02	3	3.01**	10918.2**
Loaf	1	.00	1	.14	470.4
2-Way					
MDTM X Loaf	3	.00	3	.18	288.2
Residual	32	.02	72	.22	662.2
CV(%)		23.57		16.75	18.03
MDTM	3	.02	3	3.01**	10918.2**
Linear	1	.07*	1	8.94**	32436.0**
Deviation	2	.00	2	.04	159.3
Quadratic	1	.00	1	.06	224.4
Deviation	1	.00	1	.02	94.1
Residual	36	.02	76	.21	644.9
		Tukey Separations			
0		a		c	b
10		a		bc	ab
20		a		ab	a
30		a		a	
		t Statistic			
0 vs 10		1.19		1.86	2.07*
0 vs 20		1.50		3.60**	3.95**
0 vs 30		2.08*		6.22**	6.85**
10 vs 20		.31		1.74	1.88
10 vs 30		.88		4.36**	4.78**
20 vs 30		.57		2.62*	2.90**
0 vs 10, 20,30		1.95		4.77**	5.25**

of binding strength. Both shear work and total shear force significantly decreased in a linear response with increased mechanical deboned meat substitution. Significant differences in shear work were among the following groups: 0% and 10%, 10% and 20%, and 20% and 30% in stepwise progression. No differences were detected within groupings. Shear force measurements followed this same relationship with the exception that loaves containing 30% MDTM were significantly lower than all other treatments. Increased tenderness of slices from loaves prepared with increased levels of MDTM substitution could be due to greater fluid retension or simply a result of the structure of the loaf formed by the MDTM matrix. Shear work and shear force of loaves containing soy and 100% MDTM were significantly lower than all meat substituted loaves and were not different from one another.

In general, the binding strength and shear resistance of slices decreased with increased levels of MDTM substitution.

Lipid Oxidation, TBA Test

Mean values of TBA numbers for loaves held raw and precooked foil wrapped at 4°C one week are presented in Table 15. Statistical analyses of these data are summarized in Tables 16 and 17. TBA numbers decreased with increased level of MDTM substitution for loaves held raw, cooked after being held raw (designated as raw,

Table 15. TBA Numbers[1] for Raw and Precooked Foil Wrapped Turkey Loaves Formulated with MDTM Held at 4°C One Week

Treatments % MDTM	Raw	Raw, Cooked	Precooked
0	1.40±.19	4.16±1.64	7.04±1.15
10	.99±.26	1.93± .26	6.39±2.16
20	1.05±.05	1.62± .19	3.84±1.76
30	.80±.06	1.58± .03	3.51± .61
70(30S)	1.60±.18	4.76± .19	11.64± .49

[1]Mean values and standard deviations (2 samples/treatment X 2 distillations X 2 reactions/distillation, n=8)

Table 16. Analysis of Variance of TBA Numbers for Raw and Precooked Foil Wrapped Turkey Loaves Formulated with MDTM Held at 4°C One Week

Source of Variation	df	Mean Squares
0% through 70%(30S)		
Main Effects	6	142.11**
MDTM	4	66.08**
Cooking	2	294.17**
2-Way		
MDTM X Cooking	8	19.45**
Residual	105	.84
CV(%)		26.64
0% through 30%		
Main Effects	5	72.15**
MDTM	3	25.27**
Cooking	2	142.47**
2-Way		
MDTM X Cooking	6	6.61**
Residual	84	1.03
CV(%)		35.98

Table 17. Analysis of Variance of TBA Numbers for Raw and Precooked Foil Wrapped Turkey Loaves Formulated with MDTM Held at 4°C One Week: Single Classification, Each Cooking by MDTM

Source of Variation	df	Cooking Treatment		
		Raw	Raw, Cooked	Precooked
0% through 30%				
			Mean Squares	
MDTM	3	.50**	12.16**	25.35**
Linear	1	1.20**	25.88**	69.02**
Deviation	2	.15*	5.31**	3.52
Quadratic	1	.04	9.52**	.20
Deviation	1	.25**	1.10	6.84
Residual	28	.03	.70	2.36
CV(%)		16.34	36.06	29.50
		Tukey Separations		
0				b
10		ab	a	b
20		b	a	a
30		a	a	a
		t Statistic		
0 vs 10		4.84**	5.33**	.84
0 vs 20		4.08**	6.06**	4.16**
0 vs 30		7.14**	6.17**	4.59**
10 vs 20		7.60	.74	3.32**
10 vs 30		2.30*	.84	3.75**
20 vs 30		3.06**	1.10	.43
0 vs 10, 20,30		6.56**	7.17**	3.92**

cooked), and precooked. Cooking treatments resulted in significant overall effects, increasing in value from raw; to raw, cooked; to precooked. Each group of treatments was analyzed using a single classification due to the significant MDTM level by cooking interaction. These data are presented in graphic form, Figure 1. The response trend to level of MDTM substitution varied for each cooking treatment. TBA numbers of 0% substituted loaves were significantly higher than all MDTM substitution levels for raw and raw, cooked treatments. TBA numbers for precooked loaves did not significantly differ within grouped levels of 0% and 10%, and 20% and 30%; however, significant differences were detected between these groups. Changes occurring in precooked loaves were greater than those accounted for by cooking alone. Increased TBA numbers due to cooking were quite consistent with previous reports; however, decreased TBA with increased mechanically deboned meat substitution deviated from the literature.

Mean values for TBA numbers of raw and precooked foil wrapped and vacuum sealed loaves stored at -18°C six months are presented in Table 18. Statistical analyses of these data are summarized in Table 19. Main effects for MDTM substitution level, cooking, and packaging were significant. Due to significant interactions each treatment was analyzed in a single classification (Table 20) and presented graphically in Figures 2 and 3. The response to MDTM level differed with each treatment and the pattern of

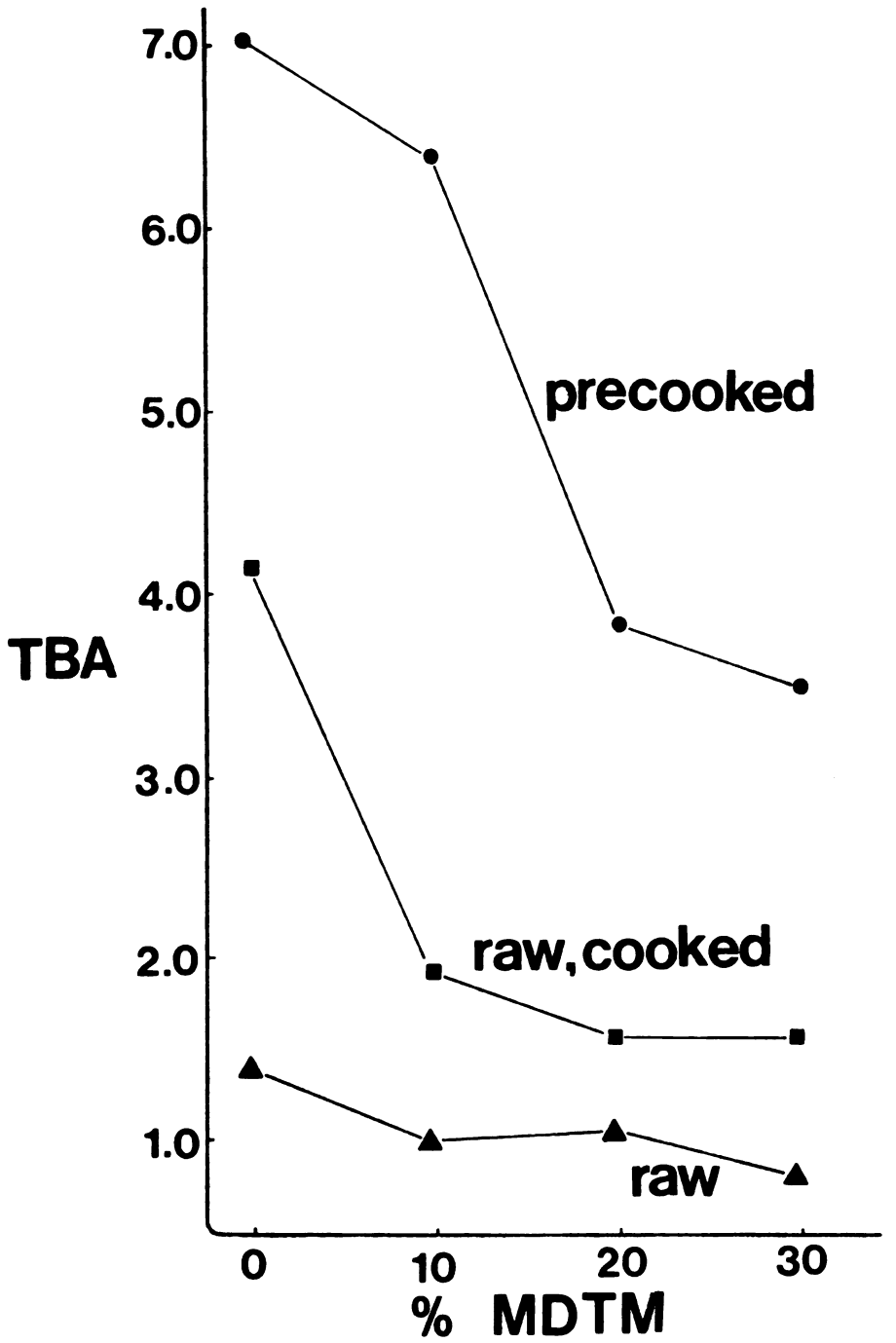


Figure 1. Changes in TBA Numbers for Raw and Precooked Foil Wrapped MDTM Substituted Turkey Loaves Held at 4°C One Week

Table 18. TBA Numbers[1] for Raw and Precooked Foil Wrapped and Vacuum Sealed Turkey Loaves Formulated with MDTM Stored at -18°C Six Months

Treatments % MDTM	Raw		Precooked	
	Foil	Vacuum	Foil	Vacuum
0	.93±.05	.55±.05	1.65±.12	.83±.01
10	1.21±.06	.68±.17	1.81±.09	.89±.05
20	.94±.10	.98±.21	1.53±.23	.84±.16
30	1.40±.48	1.37±.21	1.62±.25	1.36±.05
70(30S)	4.08±.06	2.65±.18	8.09±.40	3.98±.27

[1]Mean values and standard deviations (2 samples/treatment X 2 distillations X 2 reactions/distillation, n=8)

Table 19. Analysis of Variance of TBA Numbers for Raw and Precooked Foil Wrapped and Vacuum Sealed Turkey Loaves Formulated with MDTM Stored at -18°C Six Months

Source of Variation	df	Mean Squares
0% through 70(30S)		
Main Effects	6	63.68**
MDTM	4	81.06**
Cooking	1	24.50**
Packaging	1	33.30**
2-Way	9	8.95**
MDTM X Cooking	4	9.09**
MDTM X Packaging	4	9.03**
Cooking X Packaging	1	8.06**
3-Way		
MDTM X Cooking X Packaging	4	2.07**
Residual	140	.06
CV(%)		13.10
0% through 30%		
Main Effects	5	2.62**
MDTM	3	1.20**
Cooking	1	3.09**
Packaging	1	6.43**
2-Way	7	.58**
MDTM X Cooking	3	.26**
MDTM X Packaging	3	.55**
Cooking X Packaging	1	1.62**
3-Way		
MDTM X Cooking X Packaging	3	.08
Residual	112	.03
CV(%)		14.93

Table 20. Analysis of Variance of TBA Numbers for Raw and Precooked Foil Wrapped and Vacuum Sealed Turkey Loaves Formulated with MDTM Stored at -18°C Six Months: Single Classification, Each Cooking and Packaging Treatment by MDTM

Source of Variation	df	Cooking and Packaging Treatment			
		Raw		Precooked	
		Foil	Vacuum	Foil	Vacuum
0% through 30%					
			Mean Squares		
MDTM	3	.41**	1.06**	.11*	.50**
Linear	1	.51*	3.03**	.06	.91**
Deviation	2	.36**	.07	.14*	.30**
Quadratic	1	.06	.14*	.00	.41**
Deviation	1	.67**	.00	.26*	.19**
Residual	28	.06	.03	.04	.01
CV(%)		21.87	19.46	12.12	10.20
			Tukey Separations		
0		a	a	ab	a
10		ab	a	b	a
20		a		a	a
30		b		ab	
			t Statistic		
0 vs 10		2.30*	1.51	1.67	1.33
0 vs 20		.07	4.94**	1.32	.14
0 vs 30		3.80**	9.51**	.36	11.57**
10 vs 20		2.23*	3.43**	2.99**	1.19
10 vs 30		1.50	8.00**	2.03	10.24**
20 vs 30		3.73**	4.57**	.96	11.43**
0 vs 10, 20,30		2.52*	6.52**	.00	5.32**

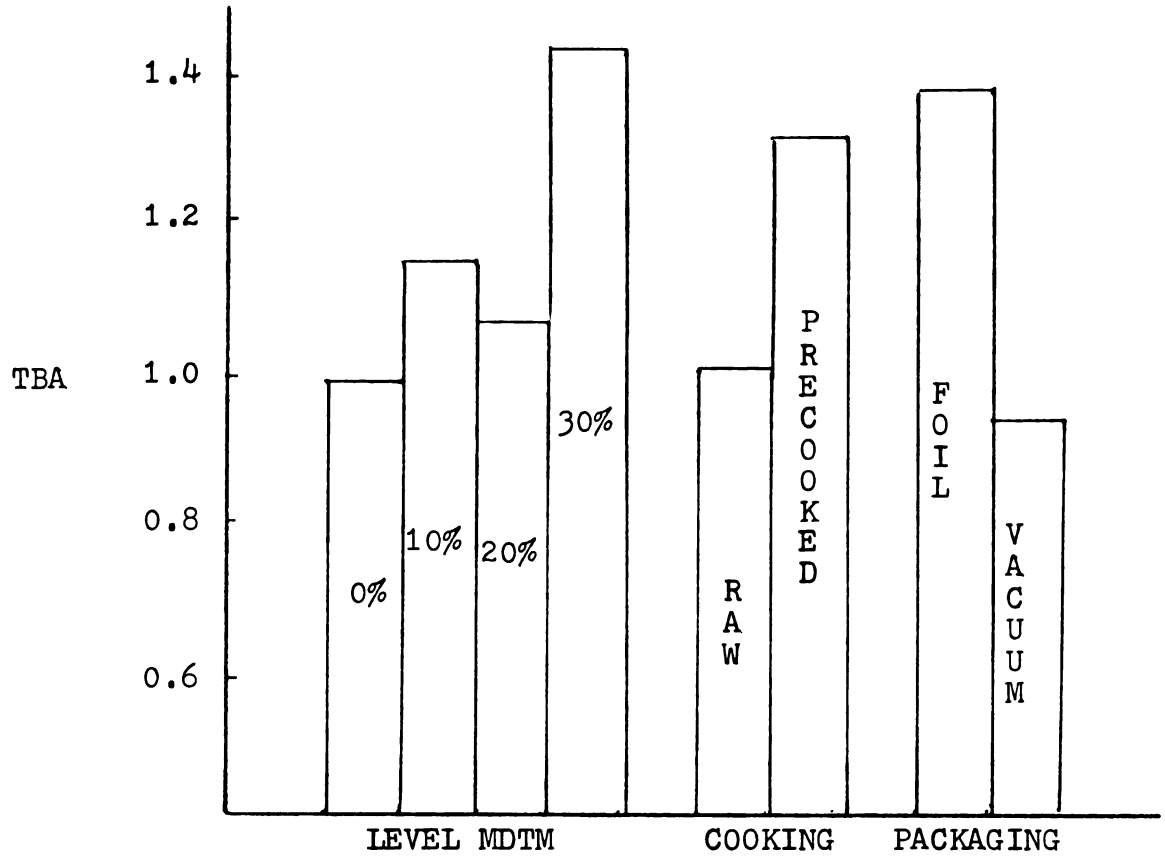


Figure 2. Main Effect Mean TBA Numbers for Raw and Precooked Foil Wrapped and Vacuum Sealed MDTM Substituted Turkey Loaves Stored at -18°C Six Months

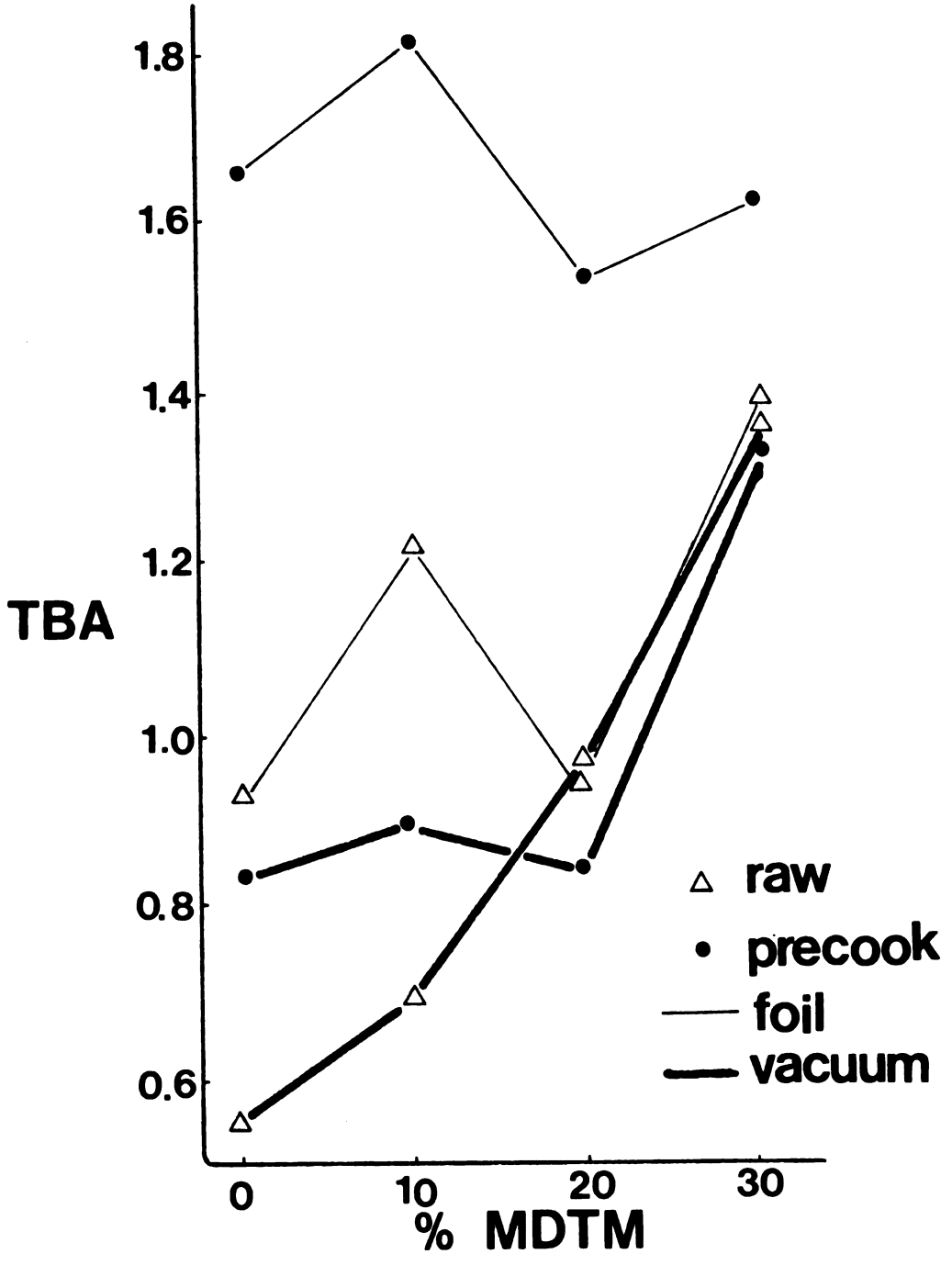


Figure 3. Changes in TBA Numbers for Raw and Precooked Foil Wrapped and Vacuum Sealed MDTM Substituted Turkey Loaves Stored at -18°C Six Months

Tukey separations was scattered. Generally under frozen storage conditions, TBA numbers increased with increased MDTM substitution levels. Loaves stored raw had significantly lower TBA numbers than those stored precooked. Vacuum packaging maintained significantly lower TBA numbers compared to foil wrapped loaves.

The significant cooking by packaging interaction was associated with the greater influence that vacuum packaging had on lowering TBA numbers of precooked loaves than raw loaves when compared to foil wrapped samples.

Sensory Evaluation

Mean values of sensory evaluation for raw and precooked loaves held at 4°C one week are presented in Table 21. Statistical analyses of these data are summarized in Table 22. No significant differences were detected either among the levels of MDTM substitution 0% through 30% or between raw and precooked samples on the flavor hedonic rating or acceptance scales. The degree of flavor difference from the 0% reference resulted in significant differences between the reference and substituted meat loaves; however, no significant differences were detected among the MDTM substituted levels. The reference was forced to "no difference" and assigned a score of 1.0 for these analyses. All meat substitutions were rated as a "slight difference from reference."

Table 21. Sensory Evaluation[1] of Raw and Precooked Foil Wrapped Turkey Loaves Formulated with MDTM Held at 4°C One Week

Treatments % MDTM	Flavor Hedonic Rating[2]	Flavor Difference[3]	Acceptance[4]
		Raw	
0	5.95±1.00	ref.	1.00±.00
10	5.50±1.76	1.95± .89	1.05±.22
20	5.40±1.23	1.95± .60	1.00±.00
30	5.10±1.77	2.25± .91	1.20±.41
70(30S)	1.65± .93	4.35±1.22	1.80±.41
		Precooked	
0	5.15±1.50	ref.	1.00±.00
10	6.15±1.14	2.35±1.04	1.10±.31
20	5.55±1.64	2.00±1.12	1.15±.37
30	5.50±1.47	2.00± .72	1.05±.22
70(30S)	1.75±1.02	3.85± .99	1.23±.37

[1]Mean values and standard deviations (n=20 panelists)

[2]Seven point scale, 7=like very much

[3]Five point scale, 1=no difference

[4]Two point decision, 1=acceptable

Table 22. Analysis of Variance of Sensory Scores of Raw and Precooked Foil Wrapped Turkey Loaves Formulated with MDTM Held at 4°C One Week

Source of Variation	df	Scoring Method: Flavor Hedonic Rating	Flavor Difference	Acceptance
0% through 70%(30S)				
			Mean Squares	
Main Effects	5	95.49**	40.71**	3.73*
MDTM	4	119.24**	50.84**	4.66*
Cooking	1	.50	.18	.02
2-Way				
MDTM X Cooking	4	3.01	1.14	.12
Residual	190	1.90	.73	.08
CV(%)		28.94	37.72	23.18
0% through 30%				
Main Effects	4	1.53	9.01**	.08
MDTM	3	1.91	11.98**	.11
Cooking	1	.40	.10	.01
2-Way				
MDTM X Cooking	3	4.02	.72	.16
Residual	152	2.14	.61	.06
CV(%)		26.42	43.02	23.27

Table 22. (cont'd.)

Source of Variation	df	Scoring Method: Flavor Hedonic Rating	Flavor Difference	Acceptance
0% through 30%, Raw			Mean Squares	
MDTM	3	2.48	5.91**	.18*
Linear	1	7.02	14.06**	.30*
Deviation	2	.21	1.84*	.12
Quadratic	1	.11	2.11*	.11
Deviation	1	.30	1.56	.12
Residual	76	2.19	.50	.05
CV(%)		26.95	39.50	21.09
			Tukey Separations	
0		a		a
10		a	a	ab
20		a	a	a
30		a	a	b
			t Statistic	
0 vs 10		.96	4.27**	.68
0 vs 20		1.18	4.27**	---
0 vs 30		1.82	5.62**	2.71**
10 vs 20		.21	.00	.68
10 vs 30		.85	1.35	2.03*
20 vs 30		.64	1.35	2.71**
0 vs 10, 20,30		1.61	5.79**	1.38

Table 22. (cont'd.)

Source of Variation	df	Scoring Method: Flavor Hedonic Rating	Flavor Difference	Acceptance
0% through 30%, Precooked			Mean Squares	
MDTM	3	3.44	6.78**	.08
Linear	1	.20	7.02**	.04
Deviation	2	5.07	6.66**	.10
Quadratic	1	5.51	9.11**	.20
Deviation	1	4.62	4.20*	.01
Residual	76	2.09	.72	.07
CV(%)		25.86	46.11	24.50
		Tukey Separations		
0		a		a
10		a	a	a
20		a	a	a
30		a	a	a
		t Statistic		
0 vs 10		2.19*	5.04**	1.20
0 vs 20		.87	3.73**	1.80
0 vs 30		.76	3.73**	.60
10 vs 20		1.31	1.31	.60
10 vs 30		1.42	1.31	.60
20 vs 30		.11	.00	1.20
0 vs 10, 20,30		1.56	5.10**	1.47

The soy substitution was significantly different from all meat substitutions. Loaves possessed a strong characteristic and objectionable soy isolate flavor and received adverse ratings on all scales.

Mean values of sensory evaluations performed on raw and precooked foil wrapped and vacuum sealed loaves after six months storage at -18°C are presented in Table 23. Statistical analyses of these data are summarized in Table 24. These evaluations were conducted on substitution levels 0%, 20%, and 30% only. Generally, differences in flavor and acceptability scores for all treatments were small. Appearance differences were small and scores generally decreased with added MDTM level and increased with precooking and vacuum sealing. The texture and moistness attributes resulted in the largest differences with changing levels of MDTM substitution. Loaves prepared with increasing levels of MDTM were more moist and tender.

The results of triangle tests performed on loaves substituted with 10% MDTM and stored raw and precooked in foil and vacuum packaging are presented in Table 25. The 10% level was used in these difference tests because it was a low substitution level and thereby, a more conservative model for cooking and packaging differences. Significant differences were detected between raw and precooked loaves under both packaging systems. An overall significant packaging difference was detected; however, individually this difference was only shown for the

Table 23. Sensory Evaluation[1] of Raw and Precooked Foil Wrapped and Vacuum Sealed Turkey Loaves Formulated with 0%, 20%, and 30% MDTM Stored at -18°C Six Months

Attributes	Raw			Precooked		
	0%	20%	30%	0%	20%	30%
Foil Wrapped						
Appearance[2]	4.9±1.3	4.8±1.5	5.2±1.4	6.0±1.1	5.2±1.5	5.2±1.3
Flavor[2]	5.0±1.5	5.0±1.4	4.9±1.7	5.2±1.6	5.3±1.4	5.2±1.3
Texture[3]	5.0±1.1	4.4±1.2	4.3±1.2	5.2±1.2	4.6±1.2	4.3±1.1
Moistness[4]	4.7±1.2	4.2±1.4	3.6±1.3	5.0±1.4	4.1±1.2	3.4±1.0
Acceptability[2]	5.0±1.4	5.0±1.4	5.0±1.4	5.0±1.6	5.2±1.4	5.2±1.1
Vacuum Sealed						
Appearance	5.2±1.3	4.9±1.4	5.4±1.2	5.9±1.1	5.4±1.3	5.1±1.5
Flavor	4.6±1.7	5.5±1.0	5.6±1.5	5.5±1.2	5.4±1.4	5.4±1.4
Texture	5.2±1.1	5.4±1.1	4.2±1.1	5.1±1.1	4.6± .9	4.5±1.2
Moistness	4.4±1.4	3.9±1.2	3.4±1.2	4.8±1.0	4.1±1.1	3.9±1.3
Acceptability	4.9±1.4	5.1±1.0	5.4±1.3	5.4±1.0	5.3±1.4	5.4±1.3

[1]Mean values and standard deviations (n=40 panelists), seven point hedonic scale

[2]Seven=like very much

[3]Seven=very firm

[4]Seven=very dry

Table 24. Analysis of Variance of Sensory Scores of Loaves Formulated with 0%, 20%, and 30% MDTM Stored at -18°C Six Months

Source of Variation	df	Sensory Attribute				
		Appearance	Flavor	Texture	Moistness	Acceptability
		Mean Squares				
Main Effects	4	8.77**	3.59	13.56**	26.07**	3.52
MDTM	2	7.28*	1.23	26.16**	49.45**	1.61
Cooking	1	18.41**	9.35*	1.63	3.85	5.85
Packaging	1	2.13	2.55	.30	1.52	5.00
2-Way	5	4.18*	2.04	.09	1.78	.27
MDTM X Cooking	2	9.61**	1.86	.06	.95	.06
MDTM X Packaging	2	.23	3.23	.10	1.74	.31
Cooking X Packaging	1	1.20	.02	.13	3.50	.60
3-Way						
MDTM X Cook. X Pack.	2	.92	3.32	.93	.70	1.26
Residual	468	1.79	2.10	1.28	1.54	1.77
CV(%)		25.44	27.87	24.28	30.19	25.83

Table 24. (cont'd.)

Source of Variation	df	Sensory Attribute: Appear.	Flavor	Texture	Moist.	Accept.
Raw, Foil Wrapped						
				Mean Squares		
MDTM	2	1.30	.41	5.31*	11.56**	.02
Linear	1	1.25	.61	9.11*	23.11**	.01
Deviation	1	1.35	.20	1.50	.00	.04
Residual	117	1.94	2.41	1.46	1.73	1.99
				Tukey Separations		
0		a	a	b	b	a
20		a	a	ab	ab	a
30		a	a	a	a	a
				t Statistic		
0 vs 20		.32	.00	2.13*	1.78	.16
0 vs 30		.80	.50	2.50*	3.64**	.08
20 vs 30		1.12	.50	.37	1.86	.08
0 vs 20,30		.28	.29	2.67**	3.13**	.14
Raw, Vacuum Sealed						
				Mean Squares		
MDTM	2	2.16	9.02*	9.16**	8.56**	2.06
Linear	1	.31	18.05**	17.11**	17.11**	4.05
Deviation	1	4.00	.00	1.20	.00	.07
Residual	117	1.71	2.09	1.19	1.67	1.65
				Tukey Separations		
0		a	a		b	a
20		a	ab	a	ab	a
30		a	b	a	a	a
				t Statistic		
0 vs 20		1.11	1.47	2.77**	1.64	.61
0 vs 30		.43	2.94**	3.79**	3.20**	1.56
20 vs 30		1.54	1.47	1.02	1.56	.96
0 vs 20,30		.40	2.54*	3.79**	2.79**	1.25

Table 24. (cont'd.)

Source of Variation	df	Sensory Attribute: Appear.	Flavor	Texture	Moist.	Accept.
Precooked,Foil Wrapped						
				Mean Squares		
MDTM	2	7.76*	.06	9.31**	24.32**	.98
Linear	1	11.25*	.01	17.11**	48.05**	1.80
Deviation	1	4.27	.10	1.50	.60	.15
Residual	117	1.74	2.06	1.35	1.46	1.89
				Tukey Separations		
0			a			a
20		a	a	a	a	a
30		a	a	a	a	a
				t Statistic		
0 vs 20		2.62**	.15	2.69**	3.42**	.73
0 vs 30		2.54*	.08	3.56**	5.74**	.98
20 vs 30		.08	.04	.86	2.31*	.99
0 vs 20,30		2.98**	.23	3.61**	5.29**	.24
Precooked,Vacuum Sealed						
				Mean Squares		
MDTM	2	6.82*	.16	3.48	8.41**	.18
Linear	1	13.61**	.05	6.61*	15.31**	.01
Deviation	1	.04	.27	.34	1.50	.34
Residual	117	1.76	1.83	1.14	1.29	1.56
				Tukey Separations		
0		b	a	b		a
20		ab	a	ab	a	a
30		a	a	a	a	a
				t Statistic		
0 vs 20		1.52	.41	1.68	2.66**	.36
0 vs 30		2.78**	.16	2.41*	3.45**	.09
20 vs 30		1.26	.25	.73	.79	.45
0 vs 20,30		2.48*	.33	2.36*	3.53**	.16

Table 25. Triangle Test of Raw and Precooked Foil Wrapped and Vacuum Sealed Turkey Loaves Formulated with 10% MDTM Stored at -18°C Six Months

Comparison[1]	Correct Decisions/Total Tastings
Cooking	
Raw vs. Precooked (overall)	51/80**
Raw vs. Precooked (foil)	25/40**
Raw vs. Precooked (vacuum)	26/40**
Packaging	
Foil vs. Vacuum (overall)	38/80**
Foil vs. Vacuum (raw)	18/40
Foil vs. Vacuum (precooked)	20/40*

[1]Cooking and packaging comparisons made in independent taste sessions

precooked loaves. Vacuum packaging compared to foil wrapping resulted in a more detectable difference with precooked than raw loaves.

Least square regression data for major attributes are presented in Table 26 as an overall summary of this substitution study. In summary, compositional changes of substituted loaves were generally a function of blended ingredients. Cooked meat yield could be attributed to increased MDTM substitution. Color and textural changes were apparent with increased mechanically deboned turkey meat. Loaves were darker though more red in color. Decreased binding strength was offset by more moist and tender loaves. TBA analyses of stored loaves resulted in differences between levels and cooking and packaging treatments. However, sensory methods generally did not satisfactorily distinguish these differences.

In Vivo Tocopherol Supplementation Study

Dressing and Mechanical Deboning

Dressing and deboning yield data are presented in Table 27. Statistical analyses of these data are summarized in Table 28. Significant differences in dressed weight were detected between sexes. Males had significantly higher dressed weights due to age and sex differentiation than female birds. These differences were normal and expected. No differences were found among

Table 26. Least Square Regression Analysis of Dependent Variables for Turkey Loaves on MDTM 0% to 30% Levels

Dependent Variable	Slope	Intercept	$r_{0\% \text{ to } 30\%}$
Composition			
Moisture	.034	73.60	-.993**
Fat	.137	.26	.995**
Protein	-.001	22.16	-.013
Ash	.001	2.03	.241
Calcium	.002	.037	.988*
pH	.004	5.74	.994**
Cooked Loaf Characteristics			
% Meat Yield	.282	75.82	.986*
% Volatile Loss	-.119	11.24	-.785
% Broth	-.144	11.46	-.842
Volume	3.03	723.80	.955*
Length	.023	16.18	.994**
Width	.023	8.43	.959*
Height	.008	6.98	.894
Calculated Volume	5.26	954.07	.998**
%ΔVolume	.154	32.04	.992**
Apparent Density	-.001	1.05	-.548
Surface Color of Cooked Slices			
Hunter Lab			
L	-.202	65.66	-.977*
a_L	.062	.98	.994**
b_L	-.007	11.85	-.711
ΔE	.184	30.00	.976*
Agtron			
436 nm	-.275	25.70	-.990**
546 nm	-.310	41.70	-.990**
585 nm	-.323	46.57	-.000**
640 nm	-.256	58.54	-.992**
Texture of Cooked Slices			
Break Work	-.004	.66	-.964*
Shear Work	-.028	3.21	-.983*
Shear Force	-.909	169.42	-.998**

Table 26. (cont'd.)

Dependent Variable	Slope	Intercept	$r_{0\% \text{ to } 30\%}$
2-Thiobarbituric Acid Test (TBA)			
Held 1 week, 4°C			
Raw	-.017	1.32	-.896
Raw, Cooked	-.081	3.53	-.843
Precooked	-.131	7.17	-.953
Stored 6 months, -18°C			
Raw			
Foil Wrapped	.012	.945	.634
Vacuum Sealed	.028	.480	.977*
Precooked			
Foil Wrapped	-.004	1.71	-.409
Vacuum Sealed	.015	.751	.781

Table 27. Dressing and Deboning Yields for Turkeys Raised with Tocopherol Supplementation

Treatments	Dressed Weight[1] kg	Pooled Dressed Weight[2] kg	Pooled Carcass Weight kg	MDTM Weight kg	Bone Residue kg	Machine Loss kg	Hand Boning[3] %	MDTM Yield[4] %	Bone Residue[5] %
Control									
Female	5.16±.40	25.80	7.55	4.45	2.53	.57	29.26	58.94	33.51
Male	8.63±1.00	43.15	11.82	7.14	3.62	1.06	27.39	60.40	30.63
Diet									
Female	4.67±.27	23.35	6.80	3.90	2.48	.42	29.55	57.35	36.47
Male	8.84±.81	44.20	12.16	7.35	4.35	.46	27.51	60.44	35.77
Inject									
Female	5.08±.50	25.40	7.08	4.17	2.37	.54	27.87	58.89	33.47
Male	8.35±.47	41.75	11.13	6.45	4.28	.40	26.65	57.95	38.45

[1]Mean values and standard deviations (n=5 birds)

[2]Total of five birds within treatments pooled for deboning

[3]$\frac{\text{Pooled Carcass Wt.}}{\text{Pooled Dressed Wt.}} \times 100$; mean & standard deviation (sex X treatment, n=6) $28.03 \pm 1.14\%$

[4]$\frac{\text{MDTM Wt.}}{\text{Pooled Carcass Wt.}} \times 100$; mean & standard deviation (sex X treatment, n=6) $59.00 \pm 1.25\%$

[5]$\frac{\text{Bone Residue}}{\text{Pooled Carcass Wt.}} \times 100$; mean & standard deviation (sex X treatment, n=6) $34.72 \pm 2.75\%$

Table 28. Analysis of Variance of Dressing and Deboning Yields for Turkeys Raised with Tocopherol Supplementation

Source of Variation	df	Mean Squares		
		Dressed Weight		
Sex	1	99.23**		
Tocopherol	2	.09		
Sex X Toco	2	.55		
Residual	24	.39		
CV(%)		9.20		
		Deboning Yield		
		Hand Boning	MDTM	Bone Residue
Sex	1	4.38*	2.17	.33
Residual	4	.51	1.42	9.37
CV(%)		2.55	2.02	8.82
Tocopherol	2	.93	.80	11.60
Residual	3	1.46	2.09	4.87
CV(%)		4.31	2.45	6.36

tocopherol treatments. The total of five birds for each sex and tocopherol treatment was pooled into one lot for hand and mechanical deboning operations. Hand boning yields were expressed as a function of carcass weight, and not edible meat as may be more commonly done, to be consistent with deboning analyses. Significant differences in percent hand boning yields were obtained between sexes. Males produced more meat per carcass than females, therefore having lower "carcass yields." To test differences in hand boning yields among tocopherol treatments, known sex differences were used as the residual term which limited the power of this analysis. No differences in hand boning yields were detected among tocopherol treatments. The overall hand boning carcass yield was 28.0%. No significant differences in mechanically deboned meat yield were detected between sexes or among tocopherol treatments. The overall yield based on initial carcass weights was 59.0%. This approximated an average of 16% additional meat obtained on an individual dressed bird basis.

Bone residue did not differ significantly for sex or tocopherol treatments. The machine loss was not calculated as a percent of carcass passed through it because, due to the nature of the machine, it should have been a finite value. In five out of the six deboning lots, the machine loss approximated 0.50 kg.

Proximate Composition

Mean values for the proximate composition of meat obtained from female and male turkeys raised with tocopherol supplementation are presented in Table 29. Analysis of variance of these data are summarized in Table 30. Meat items included breast, thigh, and MDTM. The loaf was formulated with breast meat and MDTM.

Moisture. Significant main effect differences were detected for sex and meat type. Though there was a significant sex by meat interaction, males consistently had a higher moisture content than females for all meat types within tocopherol treatments. Moisture content of meat types consistently decreased from breast to thigh to MDTM for females; but for males, moisture content decreased from thigh to breast to MDTM. The moisture content of the loaf reflected the blend of breast meat and MDTM.

Fat. Significant differences in the fat content were detected for sex and meat type. Females had higher fat levels than males. Thigh meat and MDTM obtained from females were significantly greater than that obtained from males. The significant interaction between sex and meat was associated primarily with all meat types. Males, however, had a higher fat content in the breast meat than females. These breast meat differences were relatively small and associated with the high level obtained for the male dietary tocopherol sample. Fat content of meat items

Table 29. Proximate Composition[1] of Meat from Turkeys Raised with Tocopherol Supplementation

Meat Type	Control		Diet		Inject	
	Female	Male	Female	Male	Female	Male
			% Moisture			
Breast	73.8 ± .0	74.3 ± .1	73.9 ± .2	73.9 ± .2	74.4 ± .1	74.5 ± .1
Thigh	72.3 ± .9	75.2 ± .7	72.8 ± .4	75.4 ± .6	72.0 ± 1.2	76.0 ± .9
MDTM	69.5 ± .7	72.6 ± .6	69.5 ± 1.9	71.6 ± .4	68.8 ± .6	72.6 ± .5
Loaf	72.3 ± .7	73.5 ± .2	72.8 ± .1	73.2 ± .1	73.0 ± .3	73.2 ± .5
			% Fat			
Breast	.74 ± .06	.64 ± .04	.57 ± .10	.92 ± .12	.67 ± .11	.71 ± .08
Thigh	6.93 ± 1.13	3.83 ± .67	6.42 ± .64	3.99 ± .77	7.31 ± 1.55	3.57 ± .81
MDTM	13.06 ± .52	9.21 ± .68	11.84 ± 2.70	9.31 ± .65	12.18 ± .51	8.36 ± .72
Loaf	2.65 ± .54	1.53 ± .29	1.75 ± .05	1.89 ± .09	2.52 ± .51	1.62 ± .41
			% Protein			
Breast	23.5 ± .2	22.2 ± 1.7	23.6 ± .7	25.1 ± 1.3	22.9 ± .4	23.6 ± 3.8
Thigh	19.3 ± .1	18.0 ± 1.9	19.5 ± .3	19.0 ± .3	18.8 ± 1.3	18.9 ± .8
MDTM	17.6 ± .8	17.5 ± .2	17.2 ± .7	17.3 ± .5	16.8 ± .4	17.1 ± .6
Loaf	20.6 ± .5	21.7 ± .4	20.3 ± .4	21.7 ± .5	20.3 ± .8	15.7 ± .2

[1]Mean values and standard deviations (n=3 replicate samples)

Table 29. (cont'd.)

Meat Type	Control		Diet		Inject	
	Female	Male	Female	Male	Female	Male
			% Ash			
Breast	1.12 ± .00	1.13 ± .02	1.10 ± .01	1.13 ± .02	1.14 ± .01	1.10 ± .05
Thigh	1.01 ± .02	1.03 ± .01	1.01 ± .06	1.01 ± .00	1.09 ± .05	1.01 ± .01
MDTM	1.00 ± .13	1.23 ± .09	1.02 ± .09	1.28 ± .13	1.02 ± .04	1.31 ± .02
Loaf	2.04 ± .03	1.99 ± .03	2.17 ± .02	1.98 ± .08	2.04 ± .01	2.03 ± .02
			% Calcium			
Breast	.028 ± .0	.040 ± .0	.031 ± .0	.042 ± .0	.032 ± .0	.048 ± .0
Thigh	.040 ± .0	.048 ± .0	.037 ± .0	.048 ± .0	.048 ± .0	.056 ± .0
MDTM	.156 ± .0	.176 ± .0	.152 ± .0	.168 ± .0	.156 ± .0	.280 ± .0
Loaf	.054 ± .0	.078 ± .0	.064 ± .0	.084 ± .0	.070 ± .0	.088 ± .0

Table 30. Analysis of Variance of Proximate Composition of Meat from Turkeys Raised with Tocopherol Supplementation

Source of Variation	df	Meat Component: Moisture %	Fat %	Protein %	Ash %	Calcium %
				Mean Squares		
Main Effects	6	30.96**	186.90**	65.76**	2.056**	.045**
Sex	1	56.22**	55.49**	1.06	.034**	.009**
Meat Type	3	43.08**	355.04**	125.16**	4.098**	.084**
Tocopherol	2	.15	.41	9.02**	.004	.003**
2-Way	11	3.48**	4.27**	3.59**	.029**	.001**
Sex X Meat	3	11.40**	13.76**	1.08	.102**	.001**
Sex X Toco	2	1.28	1.86	3.49	.002	.002**
Meat X Toco	6	.25	.33	4.88**	.002	.001**
3-Way						
Sex X Meat X Toco	6	.40	.14	5.95**	.006	.002**
Residual	48	.41	.66	1.24	.003	.000
CV(%)		.87	17.36	5.59	4.12	.00
Tukey LSR		2.01	2.55	3.50	.17	.00

consistently increased from breast to thigh to MDTM. The loaf reflected the blended percentage of breast meat and MDTM.

Protein. Significant differences in main effects for protein content were detected for meat type and tocopherol treatment. Protein content of meat items decreased from breast to thigh to MDTM in each sex and tocopherol treatment. Loaves reflected the blended percentage of breast meat and MDTM for all treatments. There was no consistent relationship within the significant 2- and 3-way interactions; however, these interactions were associated directly with the relatively low percentage obtained for loaves from male injected birds. This value is particularly suspect since it is lower than either breast meat or MDTM.

Ash. Significant main effect differences were detected for sex and meat type. The significant interaction between sex and meat was associated with males having consistently higher ash content for MDTM than females. With this exception there were small differences in ash content among breast, thigh, and MDTM for sex and tocopherol treatments. The ash levels of the loaves were approximately 1% higher due to the added salt and phosphate used in their formulation.

Calcium by EDTA. Significant differences were detected for all main effects and their interactions.

Small differences were distinguishable due to the relatively small residual variance of this method. Without detailing exactly where the specific differences were detected, the following statements could be made. Calcium content of meat items increased consistently from breast to thigh to MDTM for each sex and tocopherol treatment. The calcium content of MDTM was consistently four to five times greater than for either breast or thigh meat for each sex and tocopherol treatment. Loaves generally reflected the calculated blended percentage of breast and MDTM.

Lipid Oxidation, TBA Test

Meat Items. Mean values of TBA numbers for breast meat, thigh meat, and MDTM held at 4°C and stored at -18°C obtained from female and male turkeys raised with tocopherol supplementation are presented in Table 31. Statistical analyses of these data are outlined in Tables 32 through 37.

Data were initially analyzed in a 5-way analysis of variance, primarily to detect temperature differences, and are summarized in Table 32. It was noted that time was confounded with temperature in this analysis. Due to the nature of the storage conditions the time periods were not the same. Due to numerous significant interactions, these data were broken down in a stepwise manner to explore each independently. Means of overall effects are

Table 31. TBA Numbers[1] for Meat Held at 4°C and Stored at -18°C Obtained from Female and Male Turkeys Raised with Tocopherol Supplementation

Time/ Temp. Sex	Breast			Thigh			MDTM		
	Control	Diet	Inject	Control	Diet	Inject	Control	Diet	Inject
Days, 4°C									
Female									
0	.66±.08	.14±.01	.79±.01	.72±.08	.42±.04	.54±.05	.37±.01	.17±.06	.17±.00
2	.42±.02	.22±.04	.52±.08	.41±.07	.17±.04	.51±.10	.67±.01	.24±.00	.22±.02
4	.80±.01	.22±.02	.54±.04	1.30±.01	.38±.05	1.02±.02	1.24±.10	.38±.02	.63±.13
6	1.36±.07	.44±.02	.77±.01	2.80±.20	.78±.03	3.00±.16	1.86±.16	.72±.04	.99±.21
Male									
0	.52±.02	.29±.01	.32±.06	.95±.01	.38±.02	.64±.02	.60±.01	.31±.00	.40±.13
2	.86±.04	.30±.02	.38±.05	.70±.02	.36±.01	.40±.02	.95±.13	.50±.04	.40±.06
4	1.15±.01	.50±.01	.77±.01	1.00±.12	.84±.04	.63±.00	1.83±.10	.82±.02	.90±.21
6	1.52±.05	.70±.04	.44±.06	2.19±.24	2.20±.25	1.47±.01	2.78±.36	1.80±.52	1.95±.08
Months, -18°C									
Female									
0	.66±.08	.14±.01	.79±.01	.72±.08	.42±.04	.54±.05	.37±.01	.17±.06	.17±.00
1	.24±.01	.10±.01	.18±.01	.36±.11	.22±.01	.24±.03	.60±.01	.22±.06	.24±.04
2	.39±.01	.31±.01	.48±.01	.72±.01	.30±.01	.59±.01	.54±.01	.20±.00	.30±.10
3	.70±.00	.58±.00	.68±.01	.80±.00	.54±.01	.87±.01	.75±.00	.42±.10	.47±.10
Male									
0	.52±.02	.29±.01	.32±.06	.95±.01	.38±.02	.64±.02	.60±.01	.31±.00	.40±.13
1	.77±.00	.54±.01	.41±.00	.70±.04	.75±.00	.68±.01	.81±.24	.46±.04	.40±.02
2	1.40±.01	1.10±.01	.73±.03	1.23±.00	.84±.01	1.00±.15	2.38±.01	1.08±.08	.83±.08
3	.84±.01	.68±.00	.72±.00	.83±.01	.76±.01	.71±.00	1.28±.05	1.02±.28	1.22±.25

[1]Mean values and standard deviations (2 samples/treatment X 2 distillations/sample X 2 reactions/distillation, n=8)

Table 32. Analysis of Variance of TBA Numbers for Meat Held at 4°C and Stored at -18°C Obtained from Female and Male Turkeys Raised with Tocopherol Supplementation: 5-Way

Source of Variation	df	Mean Squares
Main Effects	9	5.04**
Sex	1	4.92**
Meat Type	2	1.42**
Tocopherol	2	5.15**
Temperature	1	3.06**
Time	3	8.10**
2-Way	31	.70**
Sex X Meat	2	1.02**
Sex X Toco	2	.72**
Sex X Temp	1	.57**
Sex X Time	3	.57**
Meat X Toco	4	.23**
Meat X Temp	2	.52**
Meat X Time	6	.66**
Toco X Temp	2	.52**
Toco X Time	6	.20**
Temp X Time	3	2.58**
3-Way	51	.20**
Sex X Meat X Toco	4	.17**
Sex X Meat X Temp	2	.08
Sex X Meat X Time	6	.35**
Sex X Toco X Temp	2	.16**
Sex X Toco X Time	6	.13**
Sex X Temp X Time	3	.29**
Meat X Toco X Temp	4	.01
Meat X Toco X Time	12	.08**
Meat X Temp X Time	6	.52**
Toco X Temp X Time	6	.20**
Residual (4- and 5-way and rep)	196	.03
CV(%)		24.45

Table 33. Analysis of Variance of TBA Numbers for Meat Held at 4°C and Stored at -18°C Obtained from Female and Male Turkeys Raised with Tocopherol Supplementation: 4-Way

Source of Variation	df	Temperature	
		4°C	-18°C
		Mean Squares	
Main Effects	8	5.20**	1.39**
Sex	1	1.07**	4.42**
Meat Type	2	1.83**	.11**
Tocopherol	2	4.44**	1.23**
Time	3	9.33**	1.34**
2-Way	23	.52**	.22**
Sex X Meat	2	.81**	.28**
Sex X Toco	2	.69**	.19**
Sex X Time	3	.07**	.78**
Meat X Toco	4	.13**	.11**
Meat X Time	6	1.07**	.10**
Toco X Time	6	.30**	.11**
3-Way	28	.16**	.08**
Sex X Meat X Toco	4	.25**	.05**
Sex X Meat Time	6	.25**	.15**
Sex X Toco X Time	6	.22**	.08**
Meat X Toco X Time	12	.06**	.05**
4-Way			
Sex X Meat X Toco X Time	12	.17**	.05**
Residual	72	.01	.01
CV(%)		12.04	16.13

Table 34. Analysis of Variance of TBA Numbers for Meat Held at 4°C and Stored at -18°C Obtained from Female and Male Turkeys Raised with Tocopherol Supplementation: Single Classification, Treatments over Sex by Time

Source of Variation	df	Meat Source and Tocopherol Treatment								
		Breast			Thigh			MDTM		
		Control	Diet	Inject	Control	Diet	Inject	Control	Diet	Inject
4°C					Mean Squares					
Time	3	.62**	.10**	.03	2.96**	1.21**	2.68**	2.67**	.82*	1.22**
Linear	1	1.67**	.27**	.02	6.23**	2.59**	5.58**	7.78**	2.17**	3.21**
Deviation	2	.09	.01	.03	1.33**	.51	1.23*	.12	.15	.23
Quadratic	1	.17*	.02	.00	2.65**	1.03*	2.41**	.22	.27	.46*
Deviation	1	.00	.00	.07	.00	.00	.06	.02	.02	.00
Residual	12	.03	.02	.03	.06	.19	.21	.13	.14	.10
					Tukey Separations					
0		a	a	a	ab	a	a	a	a	a
2		ab	a	a	a	a	a	ab	a	a
4		b	ab	a	b	ab	a	b	ab	a
6			b	a		b			b	
-18°C					Mean Squares					
Time	3	.13	.23	.12*	.14*	.05	.11	.71	.21	.27
Linear	1	.18	.54*	.11	.03	.14	.17	1.08	.06*	.73**
Deviation	2	.10	.07	.12*	.20*	.00	.07	.53	.02	.04
Quadratic	1	.00	.04	.12	.02**	.00	.02	.45	.00	.06
Deviation	1	.20	.11	.13	.38	.00	.13	.60	.04	.01
Residual	12	.11	.07	.03	.04	.05	.04	.32	.11	.08
					Tukey Separations					
0		a	a	a	ab	a	a	a	a	a
1		a	a	a	a	a	a	a	a	a
2		a	a	a	b	a	a	a	a	a
3		a	a		ab	a	a	a	a	a

Table 35. Analysis of Variance of TBA Numbers for Meat Held at 4°C and Stored at -18°C Obtained from Female and Male Turkeys Raised with Tocopherol Supplementation: Single Classification, Each Treatment by Time

Source of Variation	df	Meat Source and Tocopherol Treatment								
		Breast			Thigh			MDTM		
		Control	Diet	Inject	Control	Diet	Inject	Control	Diet	Inject
Female, 4°C					Mean Squares					
Time	3	.32**	.03**	.04**	2.26**	.13**	2.76**	.87**	.12**	.29**
Linear	1	.62*	.08**	.00	5.09**	.16	6.17**	2.55**	.32**	.82**
Deviation	2	.16**	.01*	.06**	.84**	.11**	1.06**	.03	.02*	.03
Quadratic	1	.31**	.01	.12**	1.65**	.21**	2.03**	.05	.03**	.05
Deviation	1	.02	.01*	.00	.04	.01	.09*	.00	.00	.01
Residual	4	.00	.00	.00	.01	.00	.01	.01	.00	.02
					Tukey Separations					
0		a	a	b	a	a	a	a	a	a
2			a	a	a		a	a	a	a
4		a	a	a		a				ab
6				b						b
Male, 4°C					Mean Squares					
Time	3	.36**	.07**	.08**	.89**	1.48**	.44**	1.90**	.88*	1.07**
Linear	1	1.08**	.20**	.05	1.62*	3.50**	.73*	5.50**	2.31**	2.65**
Deviation	2	.00	.01**	.09**	.52**	.48**	.30**	.10	.17	.28*
Quadratic	1	.00	.02*	.08	1.03**	.94**	.59*	.19	.31	.56**
Deviation	1	.00	.00	.10**	.01	.01	.00	.02	.03	.00
Residual	4	.00	.00	.00	.02	.02	.00	.04	.07	.02
					Tukey Separations					
0			a	a	a	a	a	a	a	a
2			a	a	a	a		a	a	a
4					a	a	a		ab	a
6				a					b	

Table 35. (cont'd.)

Source of Variation	df	Meat Source and Tocopherol Treatment: Breast Control	Breast Diet	Breast Inject	Thigh Control	Thigh Diet	Thigh Inject	MDTM Control	MDTM Diet	MDTM Inject
Female,-18°C					Mean Squares					
Time	3	.10**	.10**	.14**	.08**	.04**	.14**	.05**	.02*	.03**
Linear	1	.01	.24**	.00	.03	.02	.18	.12**	.05*	.09**
Deviation	2	.14**	.02**	.21**	.10**	.05**	.11**	.02**	.01	.00
Quadratic	1	.27**	.04**	.32**	.10	.10**	.17**	.00	.01	.00
Deviation	1	.02*	.00**	.11**	.11**	.00	.05**	.03**	.01	.00
Residual	4	.00	.00	.00	.00	.00	.00	.00	.00	.00
					Tukey Separations					
0		b	a		a		a		a	a
1		a	a			a			a	a
2		a			a	a	a		a	a
3		b			a				a	
Male,-18°C					Mean Squares					
Time	3	.28**	.23**	.09**	.10**	.08**	.05*	1.26**	.30**	.31**
Linear	1	.25	.30	.23**	.00	.15*	.03	1.28	.76**	.82*
Deviation	2	.29**	.20**	.02**	.15**	.05**	.06*	1.24**	.08	.05
Quadratic	1	.32	.23*	.00	.01	.10**	.05	.86	.02	.08
Deviation	1	.25**	.17**	.03**	.30**	.00	.08*	1.63**	.14	.02
Residual	4	.00	.00	.00	.00	.00	.01	.02	.02	.02
					Tukey Separations					
0				a			a	a	a	a
1				a		a	a	ab	ab	a
2				b					c	ab
3				b		a	a	b	bc	b

Table 36. Analysis of Variance of TBA Numbers for Meat Held at 4°C and Stored at -18°C Obtained from Female and Male Turkeys Raised with Tocopherol Supplementation: Single Classification, Each Time by Treatment

Source of Variation	df	Sex and Time Days 0 Female	0 Male	2 Female	2 Male	4 Female	4 Male	6 Female	6 Male
Held 4°C									
				Mean Squares					
Treatment	8	.13**	.09**	.11**	.11**	.30**	.29**	1.77**	1.10**
Residual	9	.00	.00	.00	.00	.00	.01	.02	.06
				Tukey Separations					
Breast,Control		cd	bcd	bc	cd	de	d	c	bc
Breast,Diet		a	a	ab	a	a	a	a	ab
Breast,Inject		d	ab	cd	a	c	ac	ab	a
Thigh,Control		cd		bc	bc	g	bcd	d	cd
Thigh,Diet		b	ab	a	a	ab	abcd	ab	cd
Thigh,Inject		bc	d	cd	a	ef	ab	d	bc
MDTM,Control		b	cd	d	d	fg			d
MDTM,Diet		a	a	ab	ab	ab	abcd	ab	c
MDTM,Inject		a	abc	ab	a	cd	bcd	bc	cd
				t Statistic					
Breast vs. Thigh		1.28	9.41**	.82	1.05	10.99**	.36	18.45**	7.60**
Breast vs. MDTM		10.11**	2.02	.33	3.25**	6.67**	7.30**	4.62**	9.24**
Thigh vs. MDTM		11.39**	7.39**	.49	4.30**	4.32**	6.95**	13.83**	1.64
Control vs. Diet		11.91**	12.27**	9.53**	13.99**	23.21**	11.70**	18.84**	4.28**
Control vs. Inject		2.85*	7.90**	2.79*	13.84**	11.38**	10.89**	5.86**	6.28**
Diet vs. Inject		9.07**	4.37**	6.74**	.16	11.82**	.81	12.98**	2.00

Table 36. (cont'd.)

Source of Variation	df	Sex and Time: Months 0 Female	0 Male	1 Female	1 Male	2 Female	2 Male	3 Female	3 Male
Stored -18°C									
					Mean Squares				
Treatment	8	.13**	.09**	.04**	.05**	.06**	.50**	.05**	.10**
Residual	9	.00	.00	.00	.01	.00	.00	.00	.02
					Tukey Separations				
Breast,Control		cd	bcd	ab	bc		e	de	abc
Breast,Diet		a	a	a	abc	a	cd	bcd	a
Breast,Inject		d	ab	a	a	b	a	cde	ab
Thigh,Control		cd		b	abc		de	ef	ac
Thigh,Diet		b	ab	ab	bc	a	abc	abc	ab
Thigh,Inject		bc	d	ab	abc	b	abcd	f	a
MDTM,Control			cd		c	b		ef	c
MDTM,Diet		ab	a	ab	ab		bcd	a	abc
MDTM,Inject		a	abc	ab	a	a	ab	ab	bc
					t Statistic				
Breast vs Thigh		1.33	9.41**	3.89**	2.81**	12.91**	1.43	4.12**	.25
Breast vs MDTM		10.02**	2.02	7.31**	.46	4.40**	8.83**	5.07**	5.77**
Thigh vs MDTM		11.35**	7.39**	3.42**	3.26**	17.32**	10.26**	9.19**	5.52**
Control vs Diet		11.93**	12.27**	8.85**	3.68**	25.98**	16.70**	11.25**	2.24
Control vs Inject		2.84*	7.90**	7.31**	5.54**	8.81**	20.69**	3.72**	1.39
Diet vs Inject		9.10**	4.37**	1.54	1.86	17.17**	3.99**	7.53**	.84

Table 37. Analysis of Variance of TBA Numbers for Meat Held at 4°C and Stored at -18°C Obtained from Female and Male Turkeys Raised with Tocopherol Supplementation: Single Classification, Each Time by Meat Type and Tocopherol Treatment

Source of Variation	df	Sex and Time Days 0 Female	0 Male	2 Female	2 Male	4 Female	4 Male	6 Female	6 Male
Held 4°C, Breast					Mean Squares				
Tocopherol	2	.24**	.03*	.04*	.18**	.17**	.21**	.44**	.65**
Residual	3	.00	.00	.00	.00	.00	.00	.00	.00
					Tukey Separations				
Breast, Control		a		ab					
Breast, Diet			a	a	a				
Breast, Inject		a	a	b	a				
					t Statistic				
Control vs. Diet		11.53**	5.94**	3.94*	14.02**	24.01**	38.32**	21.32**	15.68**
Control vs. Inject		2.99	5.05*	1.77	12.00**	10.76**	22.58**	13.60**	20.72**
Diet vs. Inject		14.53**	.88	5.71**	2.02	13.25**	15.74**	7.72**	5.04*
Held 4°C, Thigh					Mean Squares				
Tocopherol	2	.05*	.16**	.06*	.07**	.45**	.07*	3.01**	.35
Residual	3	.00	.00	.00	.00	.00	.00	.02	.04
					Tukey Separations				
Thigh, Control		b		ab			b	a	a
Thigh, Diet		a		a	a		ab		a
Thigh, Inject		ab		b	a		a	a	a
					t Statistic				
Control vs. Diet		4.69**	29.51**	3.22*	17.50**	29.66**	2.21	13.90**	.02
Control vs. Inject		2.77	15.93**	1.34	15.66**	9.25**	5.18**	1.30	3.61*
Diet vs Inject		1.92	13.58**	4.57*	1.82	20.41**	2.97	15.20**	3.64*

Table 37. (cont'd.)

Source of Variation	df	Sex and Time: Days 0 Female	0 Male	2 Female	2 Male	4 Female	4 Male	6 Female	6 Male
Held 4°C,MDTM				Mean Squares					
Tocopherol	2	.03*	.04	.13**	.17*	.39**	.63**	.72**	.56
Residual	3	.00	.00	.00	.01	.00	.02	.02	.13
				Tukey Separations					
MDTM,Control			a						a
MDTM,Diet		a	a	a	a	a	a	a	a
MDTM,Inject		a	a	a	a	a	a	a	a
				t Statistic					
Control vs.Diet		5.94**	3.80	29.21**	5.26**	9.11**	7.41**	7.39**	2.68
Control vs. Inject		5.94**	2.57	30.23**	6.44**	6.50**	6.85**	5.62**	2.27
Diet vs. Inject		.00	1.22	1.02	1.18	2.61	.55	1.77	.41

Table 37. (cont'd.)

Source of Variation	df	Sex and Time: Months 0 Female	0 Male	1 Female	1 Male	2 Female	2 Male	3 Female	3 Male
Stored -18°C,Breast					Mean Squares				
Tocopherol	2	.24**	.03*	.01**	.07**	.02**	.23	.01**	.01**
Residual	3	.00	.00	.00	.00	.00	.00	.00	.00
					Tukey Separations				
Breast,Control		a							
Breast,Diet			a						
Breast,Inject		a	a						
					t Statistic				
Control vs. Diet		11.50**	5.94**	11.02**	55.11**	6.53**	17.32**	---	40.41**
Control vs. Inject		2.96	5.05*	4.49*	---	7.76**	38.97**	6.12**	30.62**
Diet vs. Inject		14.46**	.88	6.53**	33.07**	14.29**	21.65**	23.27**	---
Stored -18°C,Thigh					Mean Squares				
Tocopherol	2	.05*	.16**	.01	.00	.10**	.08*	.06**	.01**
Residual	3	.00	.00	.00	.00	.00	.01	.00	.00
					Tukey Separations				
Thigh,Control		b		a	a		b		
Thigh,Diet		a		a	a		a		
Thigh,Inject		ab		a	a		ab		
					t Statistic				
Control vs. Diet		4.69*	29.51**	2.24	2.50	43.00**	4.49*	27.93**	6.06**
Control vs. Inject		2.77	15.93**	1.92	.68	13.50**	2.74	7.67**	10.39**
Diet vs. Inject		1.92	13.58**	.32	3.18*	29.50**	1.75	35.60**	4.33*

Table 37. (cont'd.)

Source of Variation	df	Sex and Time: Months 0 Female	0 Male	1 Female	1 Male	2 Female	2 Male	3 Female	3 Male
Stored -18°C,MDTM				Mean Squares					
Tocopherol	2	.03*	.04	.10**	.10	.06**	1.38**	.06*	.03
Residual	3	.00	.01	.00	.01	.00	.01	.00	.05
				Tukey Separations					
MDTM,Control			a		a				a
MDTM,Diet		a	a	a	a	a	a	a	a
MDTM,Inject		a	a	a	a	a	a	a	a
				t Statistic					
Control vs. Diet		5.94**	3.80*	9.94**	2.52	11.95**	16.17**	5.38**	1.16
Control vs. Inject		5.94**	2.58	9.55**	2.95	8.66**	19.28**	4.49*	.27
Diet vs. Inject		.00	1.22	.39	.43	3.29*	3.11	.88	.89

expressed in Figure 4. Females had lower TBA numbers than males. Breast meat had lower TBA numbers than MDTM and thigh meat; MDTM was also lower than thigh meat. TBA numbers were lowest for diet supplementation and highest for controls receiving no addition of tocopherol. TBA numbers for injected tocopherol samples were also lower than the control. Mean TBA numbers for refrigerated (4°C) holding up to six days were higher than for frozen storage (-18°C) up to three months.

Multiway analyses of variance were performed at each temperature to avoid confounding time and temperature, and are summarized in Table 33. Main effect means over sex and storage time for each meat type, tocopherol supplementation, and temperature are presented graphically in Figure 5.

Dietary tocopherol supplementation yielded lowest TBA numbers within each meat type at both temperatures, followed by the injection treatment, and finally by the control (no tocopherol supplementation), which had the highest TBA numbers. Controls had consistently higher TBA numbers than tocopherol treatments at 4°C compared to -18°C, both overall and comparing each meat individually. All meat types from control and injected birds had higher TBA numbers at 4°C than at -18°C. This trend was similar for dietary supplement with the exception that TBA numbers of breast meat were lower at 4°C than at -18°C. Reduction of TBA numbers by both tocopherol treatments was consistently greatest in breast meat, followed by MDTM,

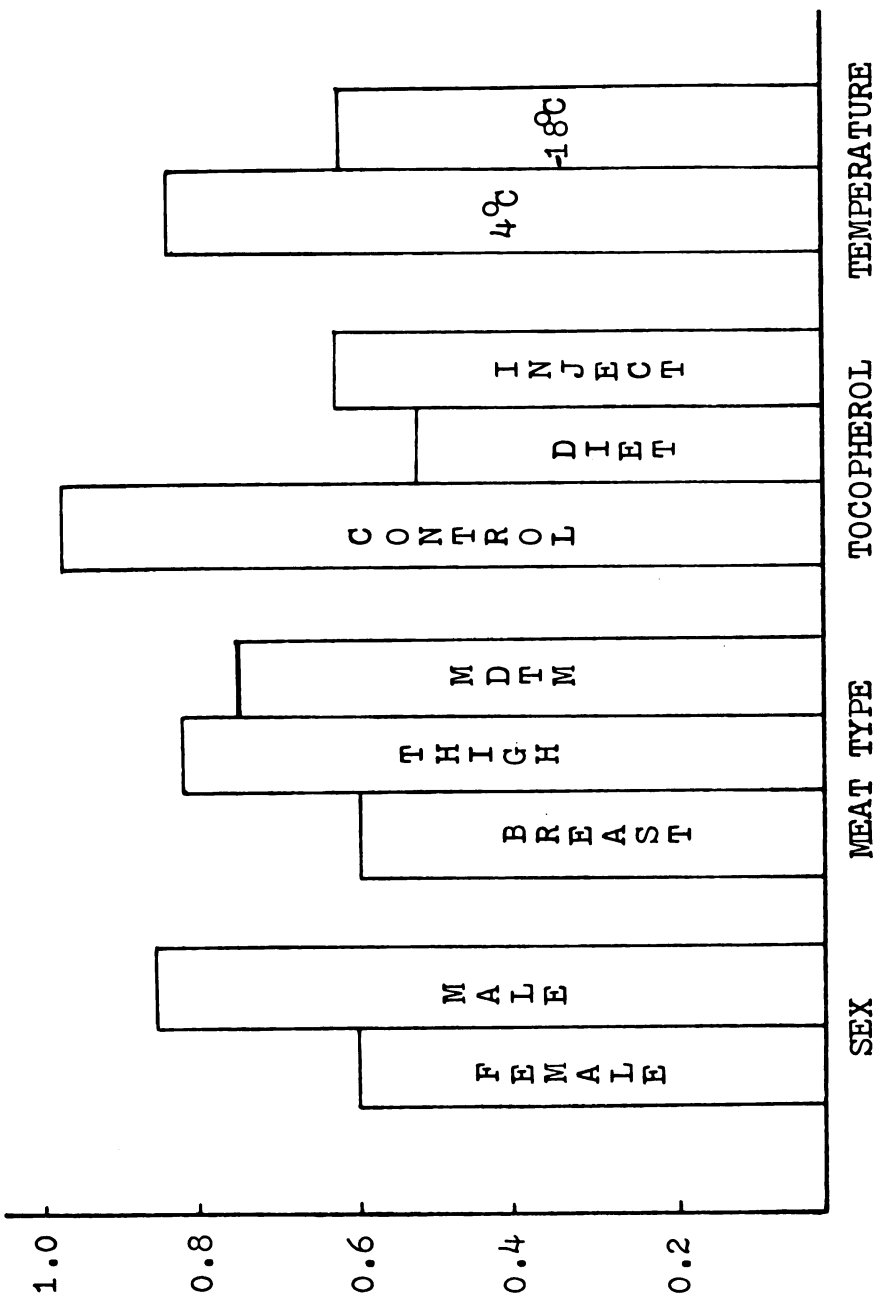


Figure 4. Overall Main Effect Mean TBA Numbers for Meat Held at 4°C and Stored at -18°C Obtained from Female and Male Turkeys Raised with Tocopherol Supplementation

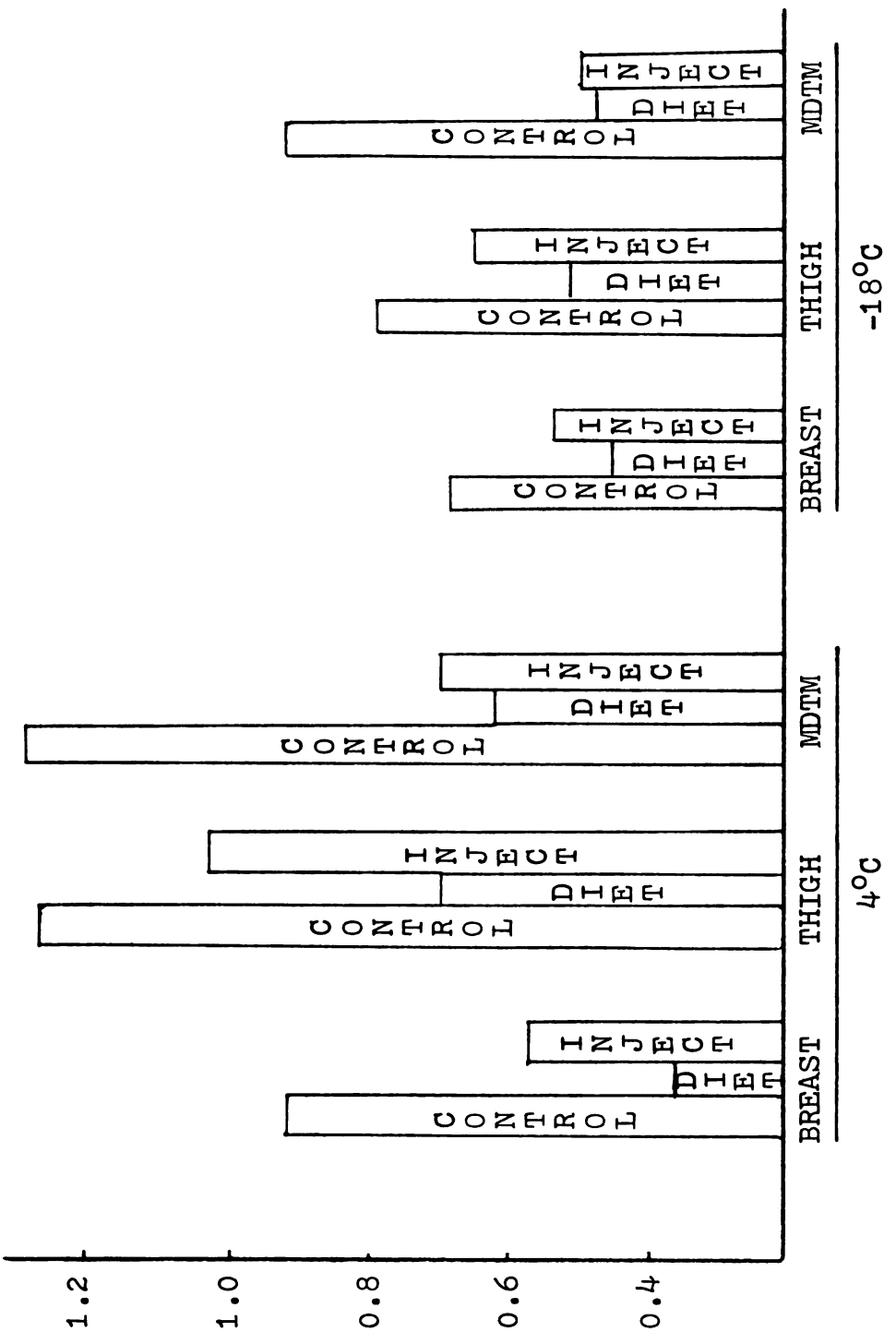


Figure 5. Main Effect Mean TBA Numbers for Tocopherol Supplemented Turkey Meat: Each Meat Type, Tocopherol Treatment, and Temperature (Mean over Sex and Time)

and then by thigh meat. Thigh meat had highest TBA values of all meats with tocopherol treatments. Injection treatment lowered TBA numbers of MDTM within each temperature to levels the same or below those of dietary treated thigh meat. Considering both tocopherol supplementation methods, breast meat had the consistently lowest TBA numbers across temperatures and meats. Individually, however, injection treated breast meat stored at -18°C had higher TBA numbers than dietary treatments of both thigh and MDTM.

Single classification analyses of variance to indicate response to time and time differences for each tocopherol treatment, meat type, and temperature by time are summarized in Table 34. Graphic presentation of these conditions are presented in Figures 6 through 11.

TBA numbers for breast meat held at 4°C up to six days are graphed in Figure 6. Control meat had initially highest TBA numbers and increased monotonically with time. Dietary supplemented tocopherol breast meat had consistently lower TBA numbers than injected breast meat. Tocopherol treatments resulted in TBA numbers less than approximately one-half of those of the control.

Tocopherol treated thigh meat held under the same conditions are presented in Figure 7. Thigh meat resulted in consistently lower TBA numbers for both tocopherol treatments when compared with the control. Diet supplementation was lower than injected thigh meat throughout the holding period. Increases in TBA numbers of thigh

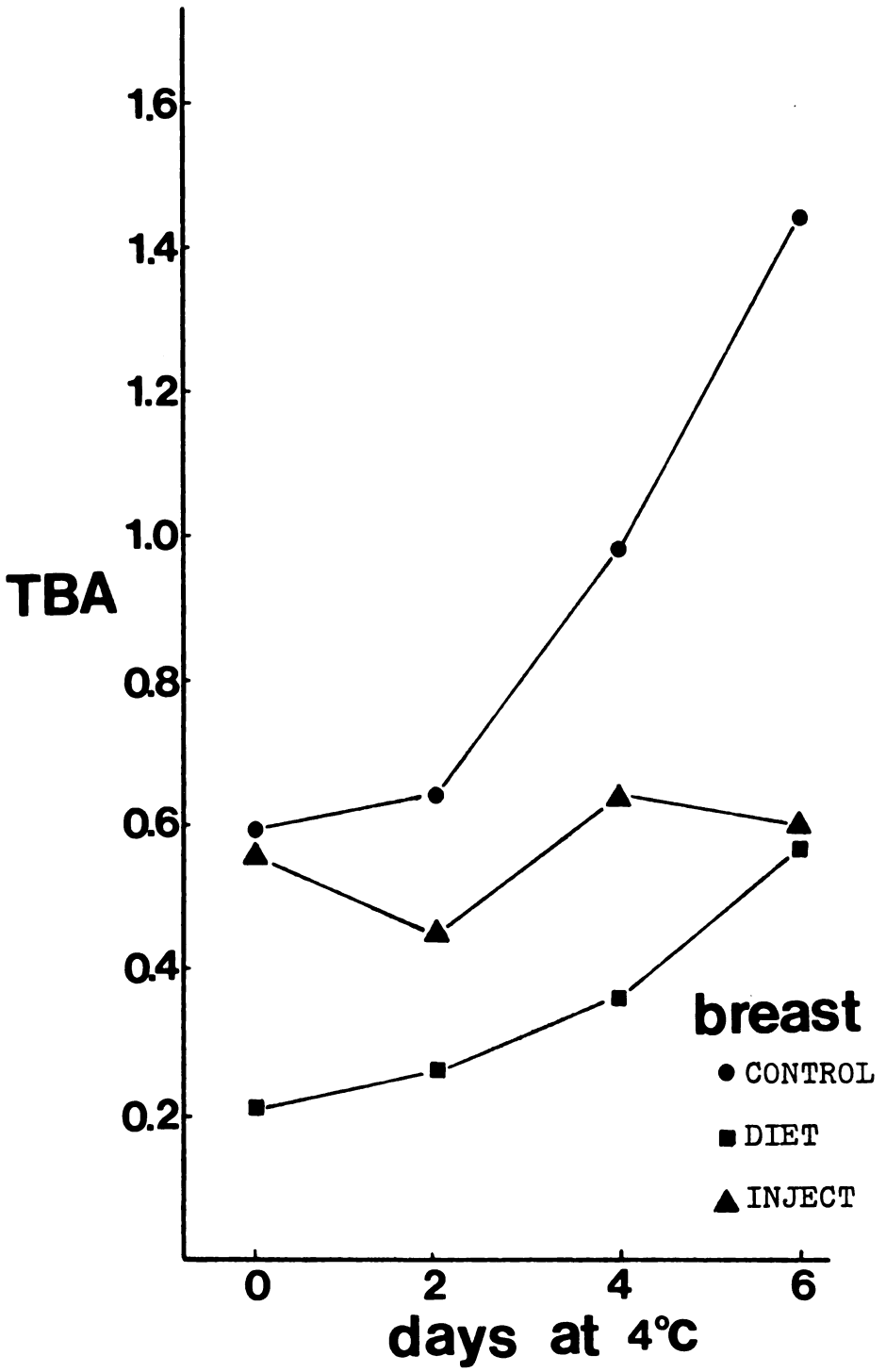


Figure 6. Mean TBA Numbers for Tocopherol Supplemented Breast Meat Held at 4°C Up to Six Days (Mean over Sex)

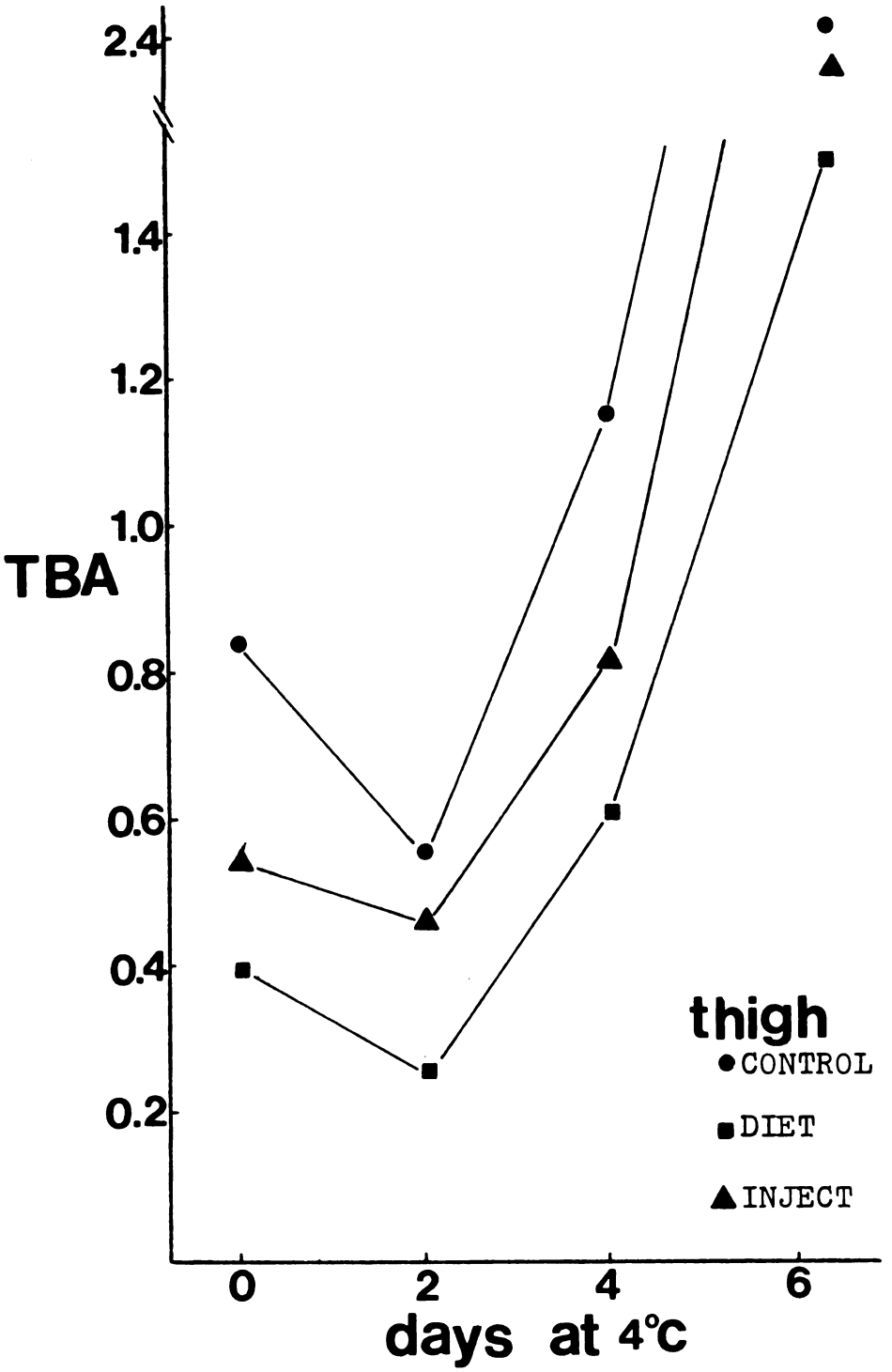


Figure 7. Mean TBA Numbers for Tocopherol Supplemented Thigh Meat Held at 4°C Up to Six Days (Mean over Sex)

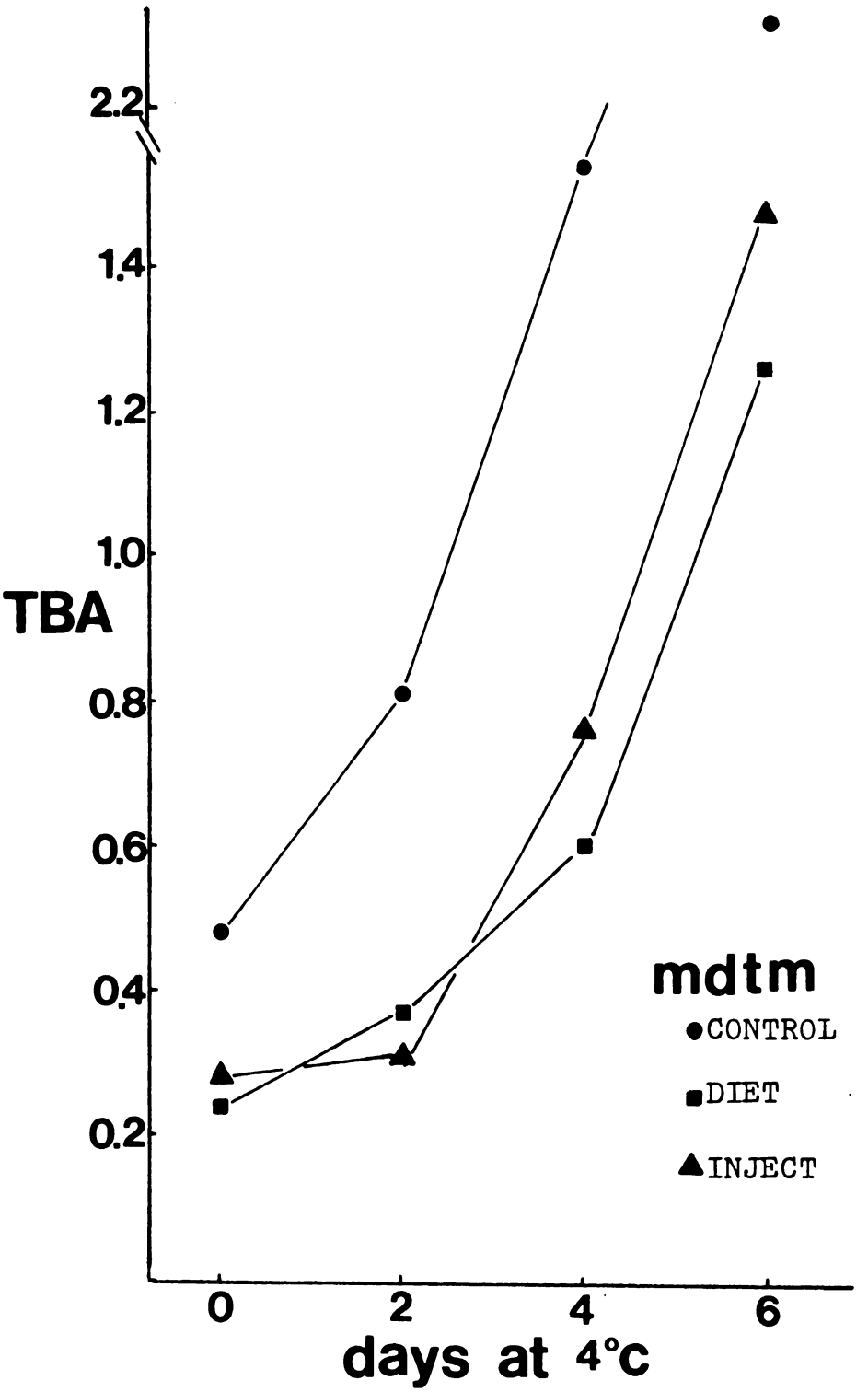


Figure 8. Mean TBA Numbers for Tocopherol Supplemented MDTM Held at 4°C Up to Six Days (Mean over Sex)

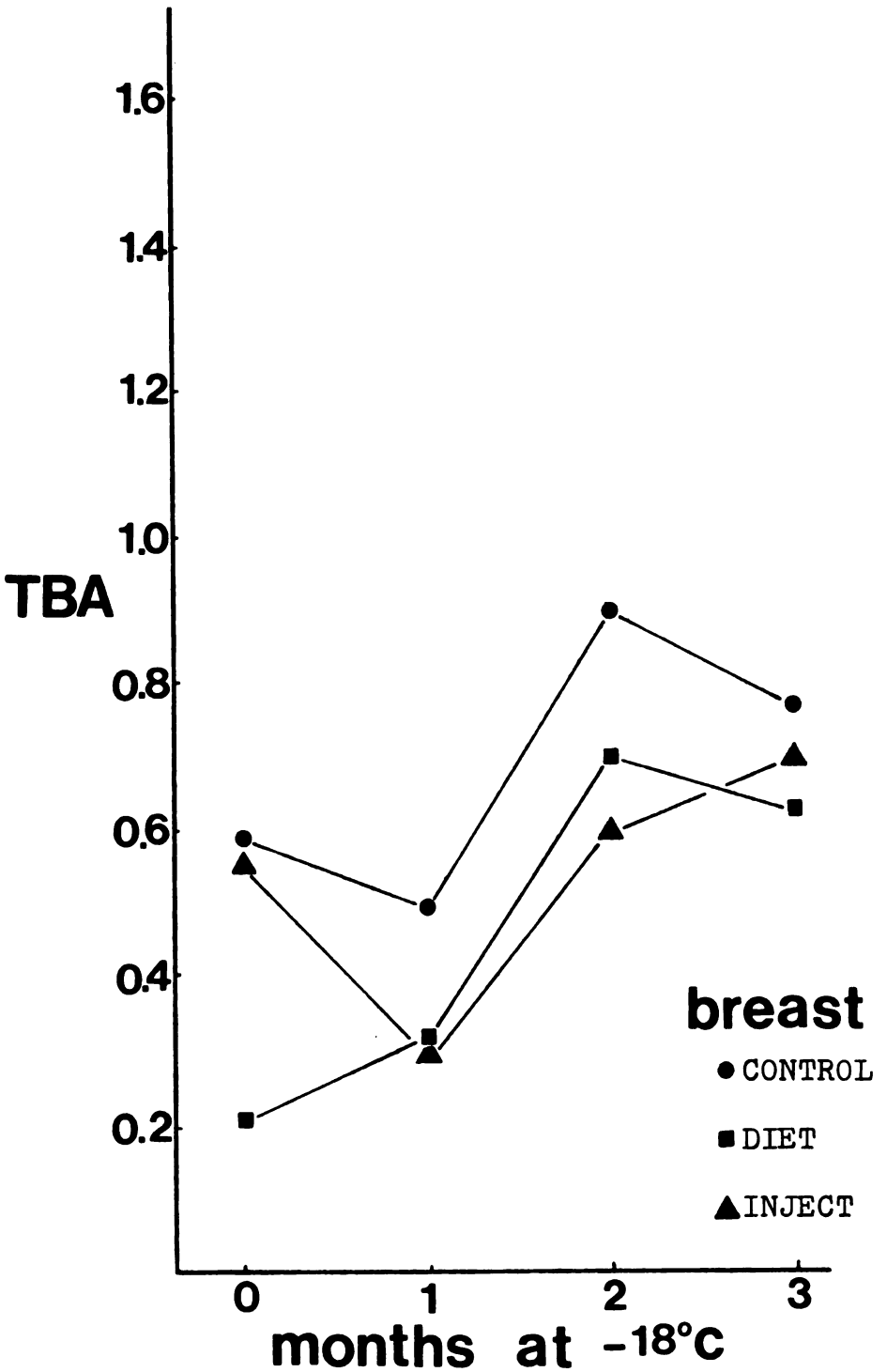


Figure 9. Mean TBA Numbers for Tocopherol Supplemented Breast Meat Stored at -18°C Up to Three Months (Mean over Sex)

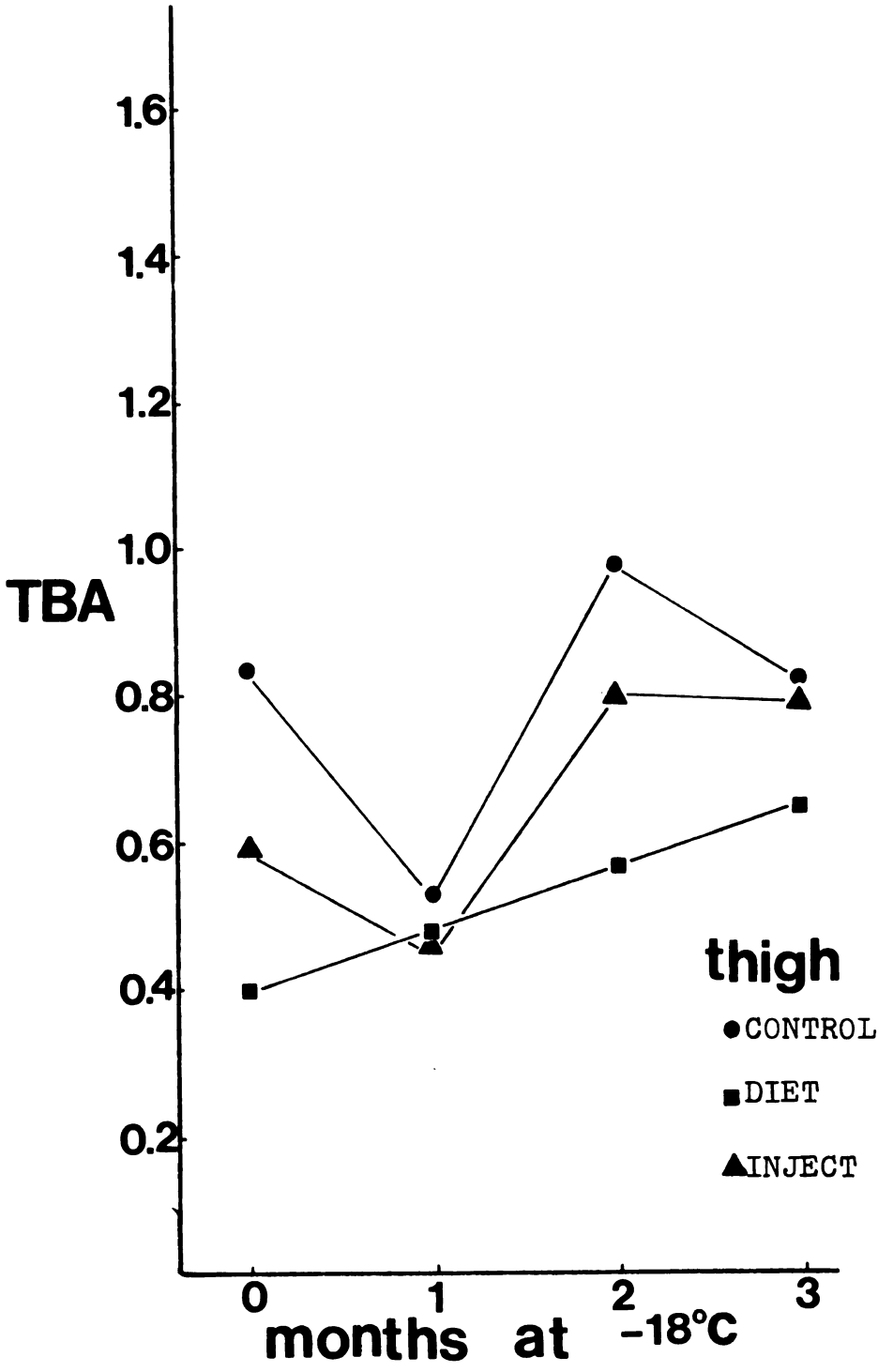


Figure 10. Mean TBA Numbers for Tocopherol Supplemented Thigh Meat Stored at -18°C Up to Three Months (Mean over Sex)

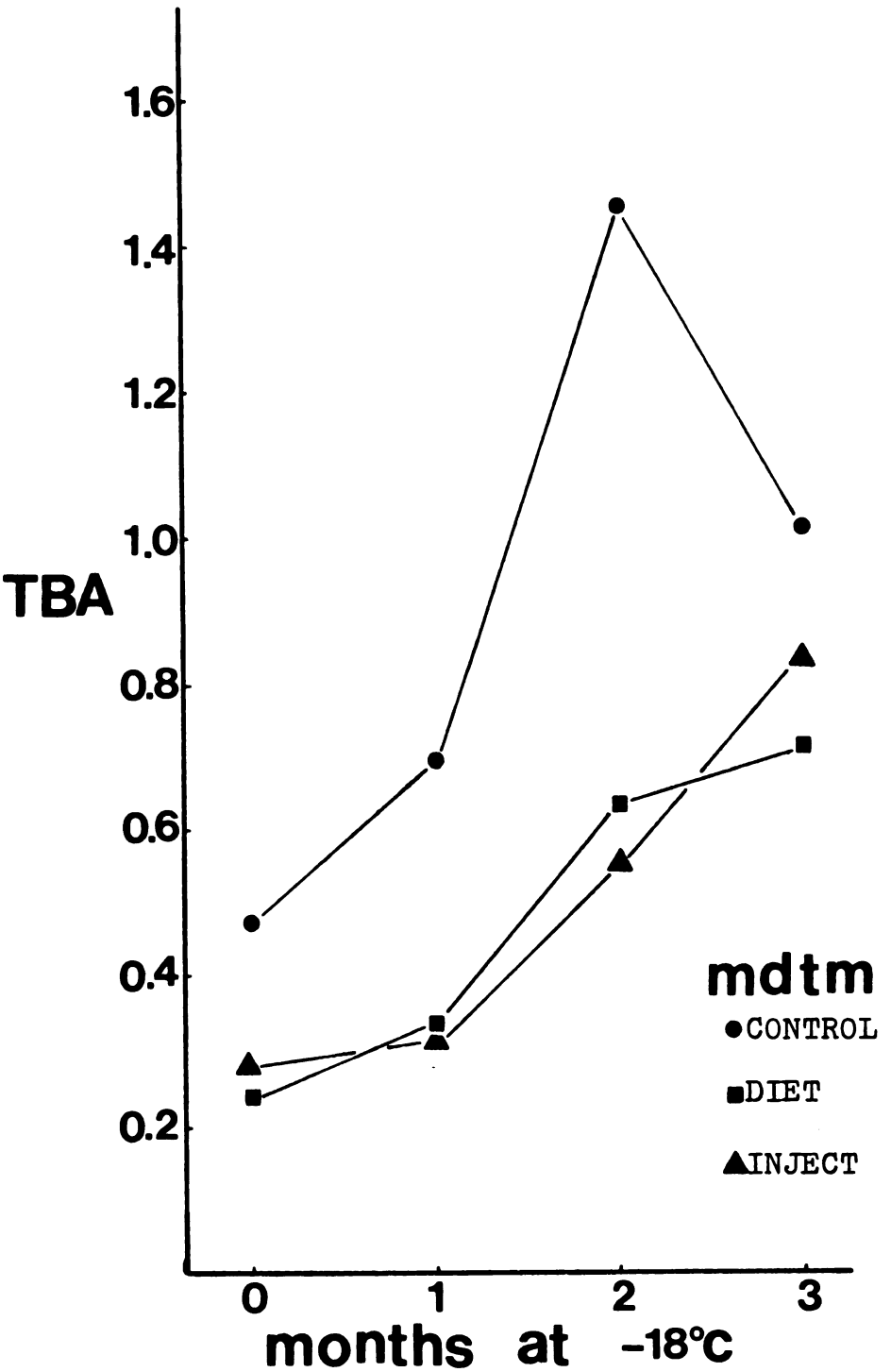


Figure 11. Mean TBA Numbers for Tocopherol Supplemented MDTM Stored at -18°C Up to Three Months (Mean over Sex)

meat were noted for all treatments and were greater than those exhibited by breast meat. Dietary tocopherol supplementation maintained TBA numbers at approximately one-half of the control for each holding time period.

MDTM treated and held under these conditions are presented in Figure 8. Tocopherol treatments were consistently lower than the control throughout the holding period. Increases in TBA numbers for all treatments occurred over time; however, tocopherol treatments were in the range of one-half of the control TBA numbers for each time period.

TBA numbers for each meat type and tocopherol treatment stored at -18°C for up to three months are illustrated in Figures 9 through 11. The TBA numbers of all meats responded similarily with time and were all in the same general range of values during the storage period. Tocopherol supplementations within each meat were consistently lower than the control. In general, the pattern of response with time at -18°C was less consistent than that shown for 4°C holding.

Single classification analysis of variance for each treatment by time are presented in Table 35. This analysis was used to express the response to holding or storage time for each sex, meat type, and tocopherol treatment. Most treatment combinations were curvilinear with time at both temperatures. Tukey separations aided in detailing the significant differences among times for

each treatment.

Statistical analyses of data for all meat and tocopherol treatments analyzed together for each temperature, time, and sex are presented in Table 36. Single classification by this breakdown enabled comparison among meat types and tocopherol treatments for each time and sex. Tukey separations delineated the significant differences. The t statistic was used to test overall meat and tocopherol treatments for each time and sex.

The comparisons of control vs. diet and control vs. inject are significantly different for each sex at each time held at $4^{o}C$. In the comparison of diet vs. inject, females followed this same trend; however, males exhibited significant differences only at day zero. TBA numbers of meat types generally differed from one another; however, in one-third of the comparisons, nonsignificant differences were shown for various combinations of meats, times, and across sexes. There was no pattern or trend detected for these nonsignificant comparisons.

Generally storage at $-18^{o}C$ resulted in similar overall comparisons as shown for $4^{o}C$. The comparisons of TBA numbers for tocopherol treatments control vs. diet and control vs. inject were significantly different for each sex and at each time, excluding three month storage of males where no significant differences among tocopherol treatments were detected. The comparison thigh vs. MDTM was significantly different at all times for each sex.

Comparisons involving breast meat exhibited the same scattered pattern of nonsignificant differences over various times and across sexes as shown for 4°C.

Single classification analysis of variance was used to separate and distinguish the effects of tocopherol treatments on each meat type. Analyses of TBA numbers for tocopherol treatments were performed separately on each meat type, temperature, time, and sex treatment combination. These analyses are summarized in Table 37. Significant differences among tocopherol treatments were shown for breast meat held at 4°C for each sampling time and both sexes. Significant differences were detailed by Tukey separations and t statistic comparisons.

Tocopherol supplementation differences in TBA numbers were shown with thigh meat held at 4°C for all times for females and all times except holding at 4°C six days for males.

MDTM held at 4°C maintained differences in TBA numbers for tocopherol treatments for all times for females and for all times for males excluding initial and after holding six days.

Tocopherol treatments maintained significant differences in TBA numbers for breast meat stored at -18°C over all times for females and over all times excluding two months storage for males.

Thigh meat stored at -18°C exhibited significant differences in TBA numbers among tocopherol treatments for

all times and sexes with the exception of one month storage where no differences were detected for either sex.

MDTM stored at -18°C exhibited significant differences in TBA numbers for all times for females and for the two month storage period for males.

A breakdown of the frequency of tocopherol treatments resulting in a significant difference in TBA numbers, as detailed through these analyses in Table 37, are presented in Table 38. Generally, summarizing tocopherol treatments from significant difference frequencies, it can be said that females responded to tocopherol treatment more frequently than males. Tocopherol treatments were more pronounced when meat was held at 4°C up to six days than when stored at -18°C up to three months. Tocopherol treatments resulting in significant differences were greatest in breast meat, then in thigh meat, and then in MDTM.

Substituted Loaves. Mean values of TBA numbers for meat loaves prepared from breast meat and MDTM obtained from female and male turkeys raised with tocopherol supplementation and held at 4°C and stored at -18°C are presented in Table 39. Statistical analyses of these data are presented in Tables 40 through 42.

Significant differences were detected among tocopherol treatments and between sex and packaging for loaves held at 4°C one week. Main effect means for these data are presented in Figure 12. TBA numbers of males were ten

Table 38. Frequency of Tocopherol Treatments Yielding A Significant Different in TBA Numbers

Main Effects	Frequency	% Significant
Sex		
Female	23/24	95.8
Male	16/24	66.6
Temperature		
4°C	21/24	87.5
-18°C	18/24	75.0
Meat Type		
Breast	15/16	93.8
Thigh	13/16	81.2
MDTM	11/16	68.8

Table 39. TBA Numbers[1] for Meat Loaves, Foil Wrapped and Vacuum Sealed, Held at 4°C and Stored at -18°C, Prepared from Meat Obtained from Female and Male Turkeys Raised with Tocopherol Supplementation

Time/Temp. Sex Raw/Cook	Control		Diet		Inject	
	Foil	Vacuum	Foil	Vacuum	Foil	Vacuum
Held 1 Week, 4°C						
Female	.23±.00	.09±.00	.16±.01	.05±.01	.16±.03	.05±.00
Male	3.00±.20	1.45±.07	1.65±.03	.62±.00	1.75±.10	.57±.01
Stored 3 Months, -18°C						
Female						
Raw	1.50±.17	1.24±.04	1.04±.15	.64±.01	1.16±.08	.81±.12
Cooked	3.05±.14	4.07±.48	1.93±.13	2.46±.03	4.60±.36	4.72±.09
Male						
Raw	1.86±.03	.84±.05	.83±.02	.57±.02	1.09±.13	.70±.06
Cooked	4.13±.16	2.92±.06	3.46±.23	2.62±.14	2.72±.17	3.54±.16
Stored 6 Months, -18°C						
Female						
Raw	1.72±.10	1.05±.05	1.00±.00	.57±.03	.80±.04	.92±.02
Cooked	1.73±.12	1.65±.08	.93±.06	1.09±.22	.98±.04	.91±.06
Male						
Raw	1.56±.00	1.81±.01	1.07±.00	1.09±.00	1.26±.00	.95±.00
Cooked	2.10±.01	1.44±.04	1.39±.00	1.26±.00	.95±.00	1.13±.00

[1]Mean values and standard deviations (2 samples/treatment X 2 distillations X 2 reactions/distillation, n=8)

Table 40. Analysis of Variance of TBA Numbers for Meat Loaves Foil Wrapped and Vacuum Sealed, Held at 4°C and Stored at -18°C, Prepared from Meat Obtained from Female and Male Turkeys Raised with Tocopherol Supplementation

Source of Variation	df	Mean Squares
Held 4°C		
Main Effects	4	4.01**
Sex	1	11.51**
Tocopherol	2	.85**
Packaging	1	2.84**
2-Way	5	.68**
Sex X Toco	2	.70**
Sex X Pack.	1	1.93**
Toco X Pack.	2	.04**
3-Way		
Sex X Toco X Pack.	2	.03**
Residual	12	.01
CV(%)		17.92

Table 40. (cont'd.)

Source of Variation	df	Mean Squares
Stored -18°C		
Main Effects	6	11.72**
Sex	1	.00
Tocopherol	2	4.05**
Packaging	1	.44*
Cooking	1	38.23**
Time	1	23.54**
2-Way	14	2.71**
Sex X Toco	2	.85**
Sex X Pack.	1	.61**
Sex X Cooking	1	.21
Sex X Time	1	1.14**
Toco X Pack.	2	.15
Toco X Cooking	2	.39*
Toco X Time	2	1.29**
Pack. X Cooking	1	.71**
Pack. X Time	1	.00
Cooking X Time	1	29.95**
3-Way	16	.49**
Sex X Toco X Pack.	2	.45**
Sex X Toco X Cooking	2	.85**
Sex X Toco X Time	2	.53**
Sex X Pack. X Cooking	1	.81**
Sex X Pack. X Time	1	.84**
Sex X Cooking X Time	1	.03
Toco X Pack. X Cooking	2	.04
Toco X Pack. Time	2	.03
Toco X Cooking X Time	2	.90**
Pack. X Cooking X Time	1	.47
Residual (4- and 5-way and rep)	59	.10
CV(%)		7.35

Table 41. Analysis of Variance of TBA Numbers for Meat Loaves, Foil Wrapped and Vacuum Sealed, Held at 4°C One Week, Prepared from Meat Obtained from Female and Male Turkeys Raised with Tocopherol Supplementation: Single Classification, Each Sex by Treatment

Source of Variation	df	Sex	
		Female	Male
Held 1 Week, 4°C			
		Mean Squares	
Treatment	5	.01**	1.59**
Residual	6	.00	.01
		Tukey Separations	
Control,Foil			
Control,Vacuum		a	b
Diet,Foil		b	b
Diet,Vacuum		a	a
Inject,Foil		b	b
Inject,Vacuum		a	a
		t Statistic	
Control vs. Diet		5.90**	15.89**
Control vs. Inject		5.90**	15.49**
Diet vs. Inject		.00	.40
Foil vs. Vacuum		16.74**	22.41**

Table 42. Analysis of Variance of TBA Numbers for Meat Loaves, Foil Wrapped and Vacuum Sealed, Stored at -18°C Three and Six Months, Prepared from Meat Obtained from Female and Male Turkeys Raised with Tocopherol Supplementation, and Evaluated Raw and Cooked: Single Classification, Sex and Cooking by Treatment

Source of Variation	df	Sex and Cooking Treatment: Female Raw	Female Cooked	Male Raw	Male Cooked
Stored 3 mo.,-18°C					
			Mean Squares		
Treatment	5	.19**	3.15**	.43**	.68**
Residual	6	.01	.06	.00	.03
		Tukey Separations			
Control,Foil		c	b		c
Control,Vacuum		bc	c	bc	ab
Diet,Foil		ab	a	abc	b
Diet,Vacuum		a	ab	a	a
Inject,Foil		bc	c	c	a
Inject,Vacuum		ab	c	ab	bc
		t Statistic			
Control vs. Diet		8.73**	9.12**	14.09**	4.21**
Control vs. Inject		4.85**	4.25**	9.88**	3.44**
Diet vs. Inject		1.88	13.37**	4.21**	.77
Foil vs. Vacuum		5.31**	5.07**	14.59**	4.34**
Stored 6 mo.,-18°C					
			Mean Squares		
Treatment	5	.30**	.28**	.22**	.31**
Residual	6	.00	.01	.00	.00
		Tukey Separations			
Control,Foil			b		
Control,Vacuum		b	b		a
Diet,Foil		ab	a	a	a
Diet,Vacuum			a	a	
Inject,Foil		a	a		
Inject,Vacuum		ab	a		
		t Statistic			
Control vs. Diet		16.92**	8.47**	148.19**	34.97**
Control vs. Inject		14.68**	9.24**	142.07**	57.82**
Diet vs. Inject		2.24	.77	43.30**	22.85**
Foil vs. Vacuum		11.02**	.02	4.00**	19.79**

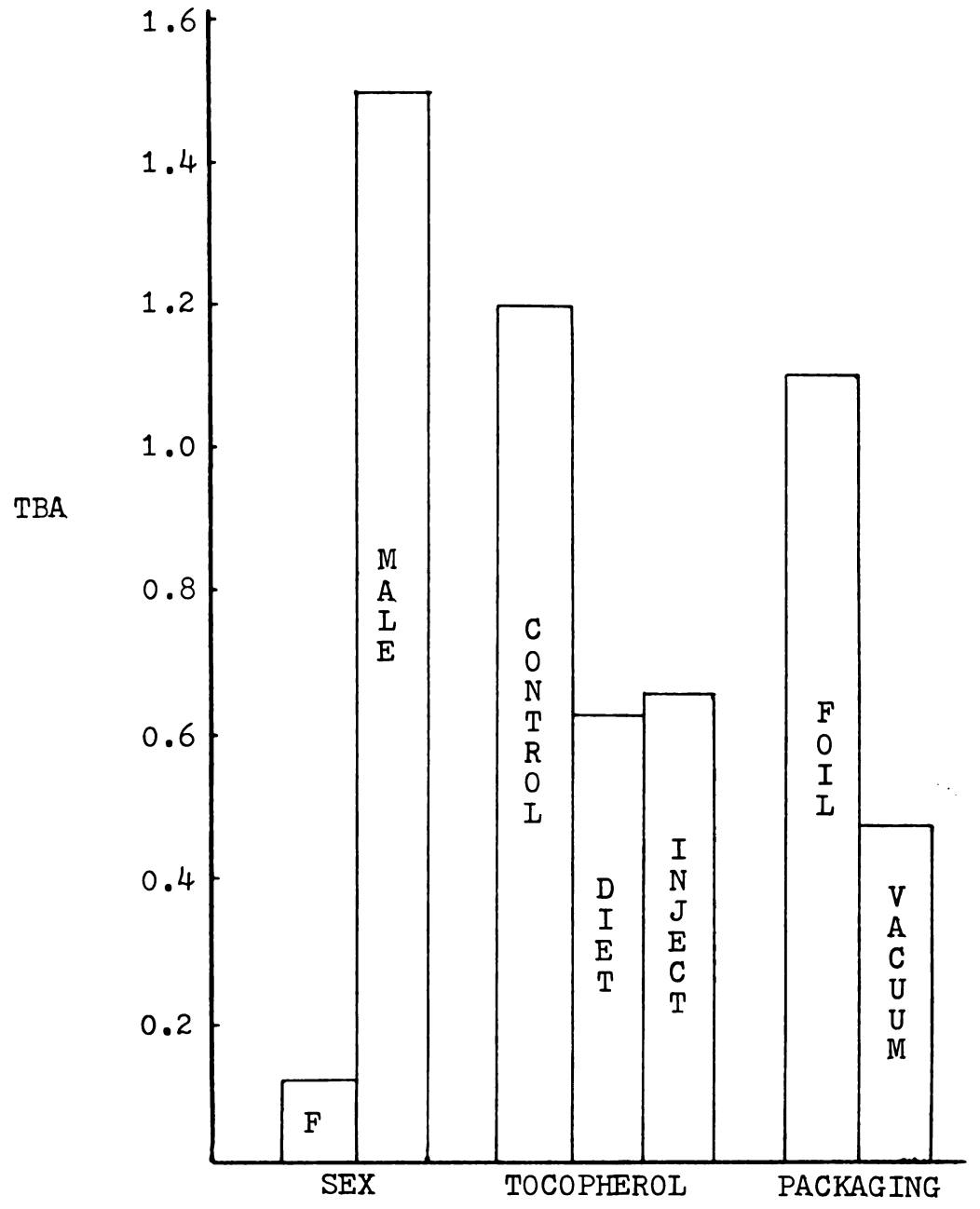


Figure 12. Overall Main Effect Mean TBA Numbers for Foil Wrapped and Vacuum Sealed Meat Loaves Held at 4°C One Week, Prepared from Meat Obtained from Female and Male Turkeys Raised with Tocopherol Supplementation

fold greater than females. Tocopherol supplementation methods were similar and both approximately one-half that of the control. Vacuum sealed loaves had TBA numbers one-half those of the foil wrapped loaves.

Single classification analyses of variance were performed to explore the significant interactions which involve all main effects. Statistical summaries are presented in Tables 41 and 42.

TBA numbers of all vacuum sealed loaves held at 4°C were significantly lower than foil wrapped loaves for females. This was similar for males with the exception that there was no difference in TBA numbers between control vacuum sealed and foil wrapped loaves (Table 41).

Meat from females had consistently lower TBA numbers than from males in all interactions involving sex. In the significant 3-way interaction, sex and packaging were non-overlapping with tocopherol treatment. All foil wrapped loaves had higher TBA numbers than vacuum sealed loaves across all tocopherol treatments and within a sex. All loaves from males had higher TBA numbers than those from females regardless of packaging or tocopherol treatment.

The t statistic comparisons for control vs. diet and control vs. inject were significantly different for each sex. Diet vs. inject comparison was not significantly different for each sex.

Significant differences in TBA numbers were detected for tocopherol treatments, packaging, cooking, and storage

time for loaves stored at -18°C (Table 42). Mean TBA numbers for main effects are presented in Figure 13. TBA numbers were similar for sex; were higher for control than diet and inject tocopherol supplementation; were higher for foil wrapping than vacuum sealing; and increased with cooking and storage time.

The t statistic comparisons for control vs. diet and control vs. inject were significantly different for each sex, cooking, and time. Diet vs. inject comparisons showed scattered significance over sex, cooking, and time. Foil wrapping vs. vacuum sealing was significantly different for each sex and cooking at three months storage. Differences were shown for these conditions at six months excluding cooked females.

MDTM Stability Study

Proximate Composition. Mean values for proximate composition of MDTM used in MDTM stability studies are presented in Table 43. Greatest variations between experimental lots were that of fluctuating moisture and fat levels. Protein, ash, and bone calcium were relatively stable. Only slight compositional differences were shown in this study between "dark" and "light" MDTM. Larger differences, however, could have been expected due to different compositional characteristics of the carcass portion deboned. Whole carcasses used in "dark" MDTM contain higher portions of skin.

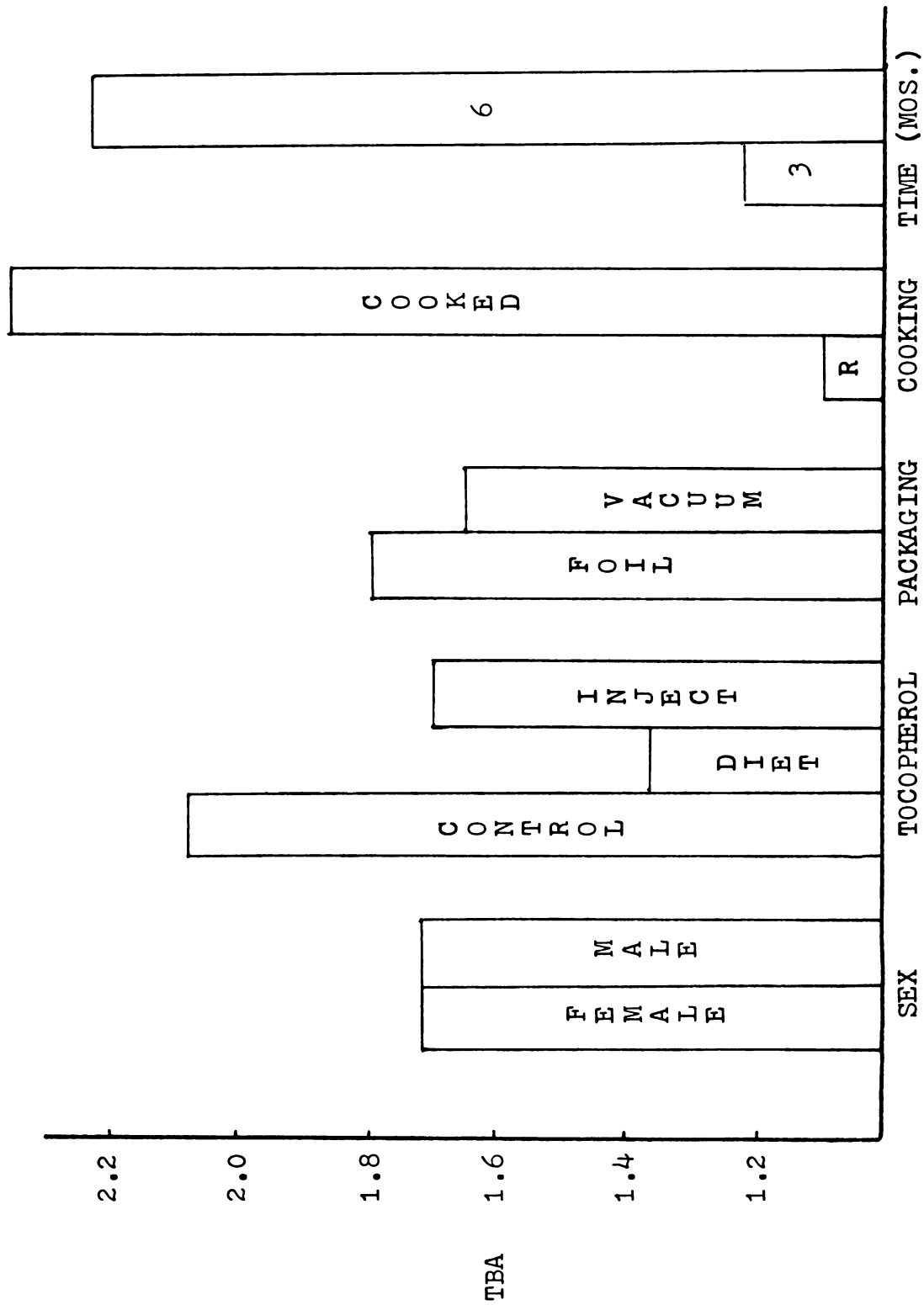


Figure 13. Overall Main Effect Mean TBA Numbers for Foil Wrapped and Vacuum Sealed Meat Loaves Stored at -18°C Three and Six Months, Prepared from Meat Obtained from Female and Male Turkeys Raised with Tocopherol Supplementation, and Evaluated Raw and Cooked

Table 43. Proximate Composition[1] of MDTM Obtained for Antioxidant and Storage Stability Experiments

Experiment	Moisture %	Fat %	Protein %	Ash %	Ca^{++} %
I. EDTA and Tenox 2	70.1±.4	12.78±.33	14.4±1.0	1.10±.01	.197±.0
II. Survey of Various Antioxidants					
Dark MDTM	73.7±.1	8.91±.09	13.5±1.2	1.08±.02	.143±.0
Light MDTM	73.6±.2	9.46±.08	15.4±1.0	1.10±.00	.167±.0
III. Mixing Stresses	69.2±.6	15.21±.88	13.2± .5	1.14±.04	.174±.0

[1]Mean values and standard deviations (2 lots X 3 replicate samples, n=6)

Experiment I. Mean TBA numbers for MDTM treated with EDTA and with Tenox 2 held at 4°C and stored at -18°C are presented in Table 44. Statistical analyses of these data are summarized in Tables 45 through 48.

Two series of analyses of variance were performed for samples held at 4°C due to missing data (Table 45). Data obtained for control, EDTA 75 ppm, Tenox 2, and Tenox 2 + EDTA 75 ppm held at 4°C one through nine days were analyzed. Significant differences were detected among treatments and holding times. The mean TBA numbers for treatments over time were control, 0.80; EDTA 75 ppm, 0.47; Tenox 2, 0.42; and Tenox 2 + EDTA 75 ppm, 0.45. Although results were scattered, TBA numbers increased with holding time. Analyses of variance of samples held at 4°C three days resulted in no significant differences among antioxidant treatments; however, all were significantly lower than the control. TBA numbers increased consistently with holding time (23 of 24 treatment X time sample combinations). No significant differences or response trends were detected for varying concentrations of EDTA.

Analyses of variance of treated samples stored at -18°C up to 12 months resulted in significant main effects among treatments and storage times, shown in Table 46. Small differences in overall means were shown for control and EDTA 50 ppm, 75 ppm, and 100 ppm treatments; however, TBA numbers of Tenox 2 samples were approximately one-third and Tenox 2 + EDTA 50 ppm, 75 ppm, and 100 ppm approximately

Table 44. TBA Numbers[1] for MDTM Treated with EDTA and Tenox 2, Held at 4°C and Stored at -18°C

Time/ Temp.	Control	EDTA 50 ppm	EDTA 75 ppm	EDTA 100 ppm	Tenox 2	Tenox 2 EDTA 50	Tenox 2 EDTA 75	Tenox 2 EDTA 100
Days								
4°C								
1	.69±.03	.36± .05	.29±.01	.34± .04	.27±.10	.26±.08	.32± .00	.24±.04
2	.56±.01	.37± .12	.34±.03	.38± .06	.38±.01	.40±.05	.30± .00	.28±.06
3	.90±.14	.67± .07	.48±.10	.42± .08	.56±.10	.44±.03	.44± .01	.36±.10
4	.98±.04	---	.47±.06	---	.42±.01	---	.48± .06	---
5	.85±.10	---	.45±.13	---	.59±.01	---	.57± .03	---
6	.86±.01	---	.55±.07	---	.41±.07	---	.52± .05	---
7	.84±.16	---	.54±.11	---	.34±.01	---	.44± .11	---
8	.80±.09	---	.58±.22	---	.46±.04	---	.54± .17	---
9	.76±.08	---	.52±.05	---	.38±.06	---	.46± .10	---
Months								
-18°C								
1	.51±.04	.89± .33	.49±.03	.52± .01	.43±.04	.60±.03	.60± .13	.51±.03
2	.98±.04	1.19± .07	.99±.13	1.12± .13	.42±.02	.62±.08	.59± .16	.51±.08
3	3.99±.99	2.65±1.02	2.96±.56	2.29± .64	.52±.01	.69±.00	.56± .04	.60±.04
6	3.33±.87	2.90±1.29	2.36±.48	2.31± .69	.46±.05	.68±.12	.66± .10	.60±.07
12	5.36±.65	6.36± .50	6.33±.96	7.37±3.26	2.64±.24	3.12±.73	4.66±2.32	3.01±.85

[1]Mean values and standard deviations (2 samples/treatment X 2 distillations/sample X 2 reactions/distillation, n=8)

Table 45. Analysis of Variance of TBA Numbers for MDTM Treated with EDTA and Tenox 2 Held at 4°C

Source of Variation	df	Mean Squares
Control;EDTA,75ppm;Tenox 2; Tenox 2 + EDTA,75ppm; 1 through 9 Days		
Main Effects	11	.20**
Treatment	3	.57**
Time	8	.06**
2-Way		
Treatment X Time	24	.01
Residual	36	.01
CV(%)		18.52
Control;EDTA,50,75,100ppm; Tenox 2;Tenox 2 + EDTA,50, 75,100ppm;1 through 3 Days		
Main Effects	9	.11**
Treatment	7	.10**
Time	2	.16**
2-Way		
Treatment X Time	14	.01
Residual	24	.01
CV(%)		23.81
Treatment	7	.10**
Residual	40	.01
Tukey Separations		
Control		a
EDTA,50ppm		a
EDTA,75ppm		a
EDTA,100ppm		a
Tenox 2		a
Tenox 2 + EDTA,50ppm		a
Tenox 2 + EDTA,75ppm		a
Tenox 2 + EDTA,100ppm		a
t Statistic		
Control vs EDTA		5.58**
Control vs Tenox 2		4.59**
Control vs Tenox 2 + EDTA		6.80**
EDTA vs Tenox 2		.04
EDTA vs Tenox 2 + EDTA		1.72
Tenox vs Tenox 2 + EDTA		1.18

Table 45. (cont'd.)

Source of Variation	df	Mean Squares
<u>EDTA,50,75,100ppm</u>		
EDTA	2	.02
Linear	1	.02
Deviation	1	.01
Residual (days & rep)	15	.01
<u>Tenox 2 + EDTA50,75,100ppm</u>		
Tenox 2 + EDTA	2	.01
Linear	1	.01
Deviation	1	.00
Residual (days & rep)	15	.01

Table 46. Analysis of Variance of TBA Numbers for MDTM Treated with EDTA and Tenox 2 Stored at -18°C

Source of Variation	df	Mean Squares
Main Effects	11	22.10**
Treatment	7	7.75**
Time	4	47.22**
2-Way		
Treatment X Time	28	1.34*
Residual	40	.63
CV(%)		41.12

Table 47. Analysis of Variance of TBA Numbers for MDTM Treated with EDTA and Tenox 2 Stored at -18°C: Single Classification, Each Treatment by Time

Source of Variation	df	Treatment							
		Control	EDTA 50	EDTA 75	EDTA 100	Tenox 2	Tenox 2 +EDTA50	Tenox 2 +EDTA75	Tenox 2+ EDTA 100
		Mean Squares							
Time	4	8.40**	9.49**	10.57**	14.69*	1.91**	2.44**	6.60*	2.47**
Linear	1	28.99**	32.08**	34.06**	44.37**	3.98*	5.16*	13.45*	5.28*
Deviation	3	1.54	1.96	2.74*	4.80	1.22**	1.53**	4.32	1.53*
Quadratic	1	.04	3.74	2.74	8.64	2.56**	3.22*	9.51*	3.28*
Deviation	2	2.29	1.07	2.74*	2.89	.56**	.68*	1.73	.65*
Cubic	1	.00	.84	1.92	3.98	.91**	1.17*	3.08	1.10*
Deviation	1	4.57*	1.31	3.55*	1.80	.21**	.20	.38	.20
Residual	5	.44	.62	.30	2.32	.01	.11	1.09	.14

Table 48. Analysis of Variance of TBA Numbers for MDTM Treated with EDTA and Tenox 2 Stored at -18°C: Single Classification, Each Time by Treatment

Source of Variation	df	Months of Storage 1	2	3	6	12
		Mean Squares				
Treatment	7	.04	.18**	3.71**	2.79**	6.38
Residual	8	.02	.01	.34	.40	2.37
		Tukey Separations				
Control		a	bcd	c	b	a
EDTA,50ppm		a	cd	abc	ab	a
EDTA,75ppm		a	d	bc	ab	a
EDTA,100ppm		a	d	abc	ab	a
Tenox 2		a	a	a	a	a
Tenox 2+EDTA,50ppm		a	abc	ab	a	a
Tenox 2+EDTA,75ppm		a	ab	a	a	a
Tenox 2+EDTA,100ppm		a	a	a	a	a
		t Statistic				
Control vs EDTA		1.11	1.53	2.85**	1.56	1.06
Control vs Tenox 2		.65	5.66**	5.93**	4.56**	1.77
Control vs Tenox 2+EDTA		.52	4.95**	7.06**	5.21**	1.40
EDTA vs Tenox 2		1.90	8.45**	4.41**	4.02**	3.22**
EDTA vs Tenox 2+EDTA		.84	9.16**	5.96**	5.17**	3.47**
Tenox vs Tenox2+EDTA		1.31	1.98	.20	.37	.77

Table 48 (cont'd.)

Source of Variation	df	Months of Storage 1	2	3	6	12
EDTA,50,75,100ppm						
		Mean Squares				
EDTA	2	.10	.02	.22	.22	.70
Linear	1	.14	.00	.13	.35	1.01
Deviation	1	.06	.03	.31	.08	.38
Residual	3	.04	.01	.58	.80	3.95
		Tukey Separations				
EDTA,50ppm		a	a	a	a	a
EDTA,75ppm		a	a	a	a	a
EDTA,100ppm		a	a	a	a	a
		t Statistic				
EDTA,50 vs EDTA,75		2.03	1.75	.40	.61	.02
EDTA,50 vs EDTA,100		1.88	.66	.47	.67	.51
EDTA,75 vs EDTA,100		.15	1.09	.87	.06	.52
Tenox 2+EDTA,50,75,100ppm						
		Mean Squares				
Tenox 2+EDTA	2	.00	.01	.01	.00	1.69
Linear	1	.01	.01	.01	.00	.00
Deviation	1	.00	.00	.01	.00	3.37
Residual	3	.01	.01	.00	.01	2.20
		Tukey Separations				
Tenox 2+EDTA,50		a	a	a	a	a
Tenox 2+EDTA,75		a	a	a	a	a
Tenox 2+EDTA,100		a	a	a	a	a
		t Statistic				
Tenox 2+EDTA,50 vs Tenox 2+EDTA,75		.00	.31	4.07*	.15	1.04
Tenox 2+EDTA,50 vs Tenox 2+EDTA,100		1.17	1.02	2.98	.76	.05
Tenox 2+EDTA,75 vs Tenox 2+EDTA,100		1.17	.72	1.10	.61	1.10

one-half of control and EDTA treatments. TBA numbers consistently increased with storage time.

Further analyses of each treatment by time (Table 47) resulted in scattered response effects. Most treatments had high order response to time indicating the complexity of changes in TBA numbers during storage. Analyses of variance for differences among treatments at each time are shown in Table 48. No significant differences were detected among treatments at the end of one month storage. After two months storage, Tenox 2 and Tenox 2+ EDTA 100 ppm treatments had significantly lower TBA numbers than the control and all EDTA treatment levels. No differences were shown among these latter treatments. After three and six months storage Tenox 2 and Tenox 2+ EDTA combinations were significantly lower than the control. EDTA 50 ppm, 75 ppm, and 100 ppm treatments were not different from the control under these same storage conditions. No significant differences were detected among treatments after 12 months storage. No significant differences or trends for varying concentrations of EDTA were detected for any storage period. These data indicate that Tenox 2 treated MDTM maintained consistently the lowest TBA numbers throughout storage. TBA numbers of meat treated with Tenox 2 were one-sixth of the control after six months and one-half after 12 months. EDTA exhibited minimum antioxidant activity and no synergistic effect with Tenox 2.

Experiment II. Mean TBA numbers for "dark" and "light" MDTM treated with various antioxidants held at 4°C and stored at -18°C are summarized in Tables 49, 50, and 51. Statistical analyses are summarized in Tables 52 through 55. Two-way analyses of variance to detect differences in meat type across storage conditions are summarized in Table 52. "Dark" MDTM consistently had higher overall TBA numbers than "light" MDTM for all time, temperature, and cooking conditions.

Significant treatment X meat interactions were detected for samples held under various conditions. The interaction involving MDTM held raw at 4°C one week appeared to be primarily associated with the 0.5% sodium chloride treatment. No significant interaction was detected for samples stored raw at -18°C for three and six months. Under these conditions "dark" MDTM had consistently higher TBA numbers than"light" MDTM for each treatment. The significant interactions for MDTM raw, cooked and for raw, cooked, held 4°C one week for storage periods of three and six months involved scattered inversions that occurred during 14% of the samplings.

Analyses of variance for each sampling condition and each meat type were conducted independently to distinguish treatment differences (Tables 53, 54, and 55). Comparisons of treatments with control and initial samples were detailed by Tukey separations. Data were scattered, therefore, Tukey separations were complex for most sample conditions.

Table 49. TBA Numbers[1] for MDTM Treated with Various Antioxidants and Held at 4°C One Week

Treatments	Dark MDTM	Light MDTM
Control	.78±.08	.61±.04
BHA	.91±.01	.70±.00
Tenox 2	1.10±.06	.88±.32
Tenox A	1.29±.07	.87±.00
Tocopherol 100 ppm	1.32±.01	.72±.18
EDTA		
50 ppm	.88±.05	.78±.12
75 ppm	.93±.04	.74±.20
100 ppm	.78±.01	.66±.12
Citric Acid		
50 ppm	1.19±.20	.83±.10
75 ppm	1.18±.18	.76±.08
100 ppm	.84±.01	.72±.13
Ascorbic Acid		
50 ppm	1.07±.06	.82±.20
75 ppm	.90±.07	.76±.20
100 ppm	.84±.03	.65±.04
Kena		
.25%	1.22±.25	.88±.40
.50%	1.06±.03	.76±.06
.75%	1.09±.04	.83±.06
NaCl		
.5%	.86±.08	1.00±.01
1.0%	1.54±.07	1.16±.31
1.5%	2.43±.03	1.45±.04

[1]Mean values and standard deviations (2 samples/treatment X 2 distillations/sample X 2 reactions/distillation, n=8); initial dark .88±.11, initial light .66±.13

Table 50. TBA Numbers[1] for MDTM Treated with Various Antioxidants and Stored Raw at -18°C Three Months

Treatments	Raw		Raw, Cooked		Cooked Held 4°C/1 Week	
	Dark	Light	Dark	Light	Dark	Light
Control	1.16±.02	.76±.13	1.52±.36	1.14±.13	2.50±.33	1.16±.03
BHA	.99±.23	.62±.04	.65±.03	.48±.05	1.67±.10	1.79±.04
Tenox 2	1.12±.28	.74±.18	.66±.09	.54±.01	4.70±.23	1.36±.12
Tenox A	.98±.23	.74±.41	.75±.03	.42±.13	1.74±.08	1.10±.05
Toco100	1.14±.03	.58±.01	.78±.02	.59±.06	3.02±.24	1.20±.06
EDTA						
50	.81±.27	.52±.06	1.42±.08	.80±.00	1.05±.12	1.08±.11
75	1.28±.23	.54±.00	1.08±.01	.62±.07	1.11±.03	.98±.17
100	.84±.14	.62±.04	1.03±.08	.54±.04	1.16±.13	1.08±.03
Citric						
50	1.36±.68	.67±.01	1.64±.50	1.24±.16	2.00±.13	4.08±.99
75	1.05±.07	.58±.04	1.34±.22	2.04±.17	5.55±.37	1.30±.06
100	.99±.06	.68±.04	2.82±.56	1.08±.28	1.47±.03	3.96±.06
Ascorbic						
50	.84±.05	.56±.02	3.18±.15	1.25±.08	2.35±.88	1.03±.08
75	.98±.08	.46±.02	1.70±.69	1.32±.05	1.34±.46	.86±.01
100	.90±.12	.54±.01	1.12±.06	1.94±.02	1.59±.18	1.27±.16
Kena						
.25%	1.17±.10	.54±.05	1.16±.06	.50±.08	1.52±.06	1.37±.31
.50%	1.16±.13	.53±.01	.66±.02	.46±.06	1.26±.52	1.00±.01
.75%	.79±.21	.81±.25	.73±.04	.38±.04	1.55±.24	.64±.04
NaCl						
.5%	1.22±.35	1.02±.05	1.23±.45	.94±.02	4.50±.99	2.09±.41
1.0%	2.19±.17	1.30±.04	1.76±.74	1.08±.06	3.71±.07	2.34±.40
1.5%	1.72±.11	1.54±.25	1.66±.30	1.19±.06	2.04±.25	3.66±.04

[1]Mean values and standard deviations (2 samples/treatment X 2 distillations/sample X 2 reactions/distillation, n=8); initial dark .88±.11, initial light .66±.13

Table 51. TBA Numbers[1] for MDTM Treated with Various Antioxidants and Stored Raw at -18° Six Months

Treatments	Raw		Raw, Cooked		Cooked Held 4°C/1 Week	
	Dark	Light	Dark	Light	Dark	Light
Control	1.28±.44	.98±.28	1.80±.11	1.20±.35	2.34±.28	1.95±.08
BHA	1.02±.04	.84±.38	1.10±.35	.72±.06	1.73±.07	1.42±.01
Tenox 2	.87±.06	.64±.09	.77±.20	.64±.02	1.52±.09	1.36±.24
Tenox A	.88±.07	.58±.08	.87±.14	.55±.01	1.40±.23	1.02±.08
Toco100	1.37±.30	.92±.26	1.20±.29	.73±.26	1.98±.26	1.22±.09
EDTA						
50	1.28±.01	.74±.11	1.08±.12	.79±.01	1.78±.20	1.52±.12
75	1.23±.62	.68±.04	1.45±.57	.71±.01	1.52±.08	1.01±.26
100	1.20±.08	1.26±.56	.95±.21	.94±.04	1.71±.07	1.54±.44
Citric						
50	1.38±.23	.87±.04	2.18±.78	1.48±.04	2.52±.22	1.96±.33
75	1.96±.53	.76±.10	2.62±.57	1.47±.52	2.35±.31	1.12±.01
100	1.20±.12	1.12±.12	2.12±.01	1.49±.03	2.46±.47	1.64±.22
Ascorbic						
50	1.02±.20	.57±.03	2.89±.37	.94±.12	2.94±.01	1.41±.17
75	1.06±.11	.59±.00	3.66±.57	1.55±.59	3.60±.33	2.32±.09
100	1.18±.15	1.24±.13	1.48±.09	1.32±.28	1.82±.29	2.02±.22
Kena						
.25%	1.26±.29	.54±.02	1.99±.08	.84±.20	3.57±.99	1.97±.52
.50%	1.01±.24	.51±.06	1.95±.99	.65±.00	1.51±.04	.93±.10
.75%	1.09±.17	.62±.11	1.28±.05	.77±.01	1.58±.23	.98±.26
NaCl						
.5%	1.07±.20	1.19±.35	1.22±.08	1.70±.13	1.90±.42	6.23±.99
1.0%	1.72±.02	1.20±.04	2.82±.02	2.66±.10	2.50±.18	2.66±.12
1.5%	2.38±.11	1.72±.36	2.50±.03	1.42±.15	2.59±.17	1.68±.07

[1]Mean values and standard deviations (2 samples/treatment X 2 distillations/sample X 2 reactions/distillation, n=8); initial dark .88±.11, initial light .66±.13

Table 52. Analysis of Variance of TBA Numbers for MDTM Treated with Various Antioxidants

Source of Variation	df	Meat Condition: 4°C 1 Week Raw	-18°C 3 Months Raw	-18°C 3 Months Raw, Cooked	-18°C 3 Months Cooked, Held	-18°C 6 Months Raw	-18°C 6 Months Raw, Cooked	-18°C 6 Months Cooked, Held
		Mean Squares						
Main Effects	21	.36**	.46**	1.11**	3.35**	.51**	1.76**	2.21**
Treatments	20	.29**	.31**	.95**	3.13**	.38**	1.41**	2.18**
Meat	1	1.60**	3.51**	4.32**	7.71**	3.11**	8.80**	2.78**
2-Way Treatments X Meat	20	.05**	.05	.29**	2.55**	.09	.40**	1.41**
Residual	42	.02	.03	.06	.18	.06	.10	.20
CV(%)		14.73	15.89	22.47	46.11	23.11	22.11	23.29

Table 53. Analysis of Variance of TBA Numbers for MDTM Treated with Various Antioxidants and Held at 4°C One Week

Source of Variation	df	Meat Source: Raw Dark	Meat Source: Raw Light
		Mean Squares	
Treatment	20	.27**	.07*
Residual	21	.01	.03
		Tukey Separations	
Control		a	a
BHA		abc	a
Tenox 2		abcd	ab
Tenox A		cde	ab
Tocopherol, 100 ppm		de	a
EDTA, 50 ppm		ab	ab
EDTA, 75 ppm		abc	a
EDTA, 100 ppm		a	a
Citric Acid, 50 ppm		bcde	ab
Citric Acid, 75 ppm		bcde	ab
Citric Acid, 100 ppm		ab	a
Ascorbic Acid, 50 ppm		abcd	ab
Ascorbic Acid, 75 ppm		ab	ab
Ascorbic Acid, 100 ppm		ab	a
Kena, .25%		bcde	ab
Kena, .50%		abcd	ab
Kena, .75%		abcd	ab
NaCl, .5%		ab	ab
NaCl, 1.0%		e	ab
NaCl, 1.5%			b
Initial		ab	a
		t Statistic	
Type I vs. EDTA		4.31**	.90
Type I vs. Citric		.58	.44
Type I vs. Ascorbic		2.96**	.74
Type I vs. Kena		.43	.07
EDTA vs. Citric		-3.73**	.46
EDTA vs. Ascorbic		1.34	.15
EDTA vs. Kena		-4.74**	.96
Citric vs. Ascorbic		2.38*	.30
Citric vs. Kena		1.01	.51
Ascorbic vs. Kena		-3.39**	.81

Table 54. Analysis of Variance of TBA Numbers for MDTM Treated with Various Antioxidants Stored Raw at -18°C Three Months

Source of Variation	df	Meat Source and Condition: Raw Dark	Raw Light	Raw,Cooked Dark	Raw,Cooked Light	Cooked,Held Dark	Cooked,Held Light
				Mean Squares			
Treatment	20	.22**	.15**	.90**	.34**	3.51**	2.17**
Residual	21	.05	.02	.10	.01	.25	.11
				Tukey Separations			
Control		ab	abc	a	de	abcd	abc
BHA		ab	ab	a	a	ab	abc
Tenox 2		ab	ab	a	ab	ef	abc
Tenox A		ab	ab	a	a	abc	abc
Toco,100ppm		ab	ab	a	ab	bcde	abc
EDTA,50ppm		ab	ab	a	abcd	ab	abc
EDTA,75ppm		abc	ab	a	ab	ab	ab
EDTA,100ppm		ab	ab	a	ab	ab	abc
Citric,50ppm		abc	ab	ab	e	abc	d
Citric,75ppm		ab	ab	a		f	abc
Citric,100ppm		ab	ab	bc	cde	ab	d
Ascorbic,50ppm		ab	ab	c	e	abc	abc
Ascorbic,75ppm		ab	a	ab	e	ab	ab
Ascorbic,100ppm		ab	ab	a	bcde	ab	abc
Kena,.25%		ab	ab	a	a	ab	abc
Kena,.50%		a	ab	a	a	ab	ab
Kena,.75%		a	abc	a	a	ab	a
NaCl,.5%		ab	bcd	a	bcde	def	bc
NaCl,1.0%		c	cd	ab	cde	cdef	c
NaCl,1.5%		bc	d	ab	de	abc	d
Initial		ab	ab	a	abc	a	a
				t Statistic			
Type I vs.EDTA		.40	1.74	-2.64*	-2.89**	5.51**	1.98
Type I vs. Cit.		.78	.71	-6.75**	-16.20**	1.05	-9.04**
Type I vs. Asc.		.94	2.30*	-7.13**	-11.58**	3.25**	1.94
Type I vs. Kena		.09	.88	.86	.50	4.35**	2.19*
EDTA vs. Cit.		1.18	1.03	-4.11**	-13.30**	-6.56**	-11.02**
EDTA vs. Asc.		.54	.56	-4.48**	-8.68**	-2.25*	.04
EDTA vs. Kena		.49	.86	1.78	3.40**	1.16	.21
Cit. vs. Asc.		1.72	1.59	.37	4.62**	4.30**	10.98**
Cit. vs. Kena		.69	.17	5.89**	16.70**	5.40**	11.23**
Asc. vs. Kena		1.02	1.42	6.26**	12.08**	1.09	.25

Table 55. Analysis of Variance of TBA Numbers for MDTM Treated with Various Antioxidants Stored Raw at -18°C Six Months

Source of Variation	df	Meat Source and Condition: Raw Dark	Raw Light	Raw,Cooked Dark	Raw,Cooked Light	Cooked,Held Dark	Cooked,Held Light
				Mean Squares			
Treatment	20	.27**	.20**	1.28**	.53**	.97**	2.61**
Residual	21	.06	.04	.15	.05	.21	.20
				Tukey Separations			
Control		ab	ab	abcde	abcd	abcd	ab
BHA		ab	a	abc	abc	abc	ab
Tenox 2		a	a	a	ab	ab	ab
Tenox A		a	a	a	a	ab	ab
Toco,100ppm		abc	ab	abc	abc	abcd	ab
EDTA,50ppm		ab	a	abc	abc	abcd	ab
EDTA,75ppm		ab	a	abcde	abc	ab	ab
EDTA,100ppm		ab	ab	ab	abcd	ab	ab
Citric,50ppm		abc	ab	abcdef	bcd	abcd	ab
Citric,75ppm		bc	a	cdef	bcd	abcd	ab
Citric,100ppm		ab	ab	abcdef	bcd	abcd	ab
Ascorbic,50ppm		ab	a	ef	abcd	bcd	ab
Ascorbic,75ppm		ab	a	f	cd	d	ab
Ascorbic,100ppm		ab	ab	abcde	abcd	abcd	ab
Kena,.25%		ab	a	abcde	abcd	cd	ab
Kena,.50%		ab	a	abcde	ab	ab	ab
Kena,.75%		ab	a	abcd	abc	ab	ab
NaCl,.5%		ab	ab	abc	d	abcd	
NaCl,1.0%		abc	ab	def		abcd	b
NaCl,1.5%		c	b	bcdef	abcd	abcd	ab
Initial		a	a	a	ab	a	a
				t Statistic			
Type I vsEDTA		-2.14*	1.64	1.10	1.41	.44	.34
Type I vs Cit.		-4.04**	1.84	-6.15**	-6.63**	-3.38**	1.20
Type I vs Asc.		1.13	.87	-7.80**	-4.50**	-4.68**	-2.52*
Type I vs Kena		1.35	1.12	-3.66**	.92	-2.54*	.04
EDTA vs Cit.		1.89	.20	-5.04**	-5.22**	-2.94**	.86
EDTA vs Asc.		1.02	.77	-6.69**	-3.58**	-4.24**	-2.18*
EDTA vs Kena		.80	2.76*	-2.55*	.50	-2.10*	.30
Cit. vs Asc.		2.91**	.97	1.65	1.64	1.30	1.32
Cit. vs Kena		2.69*	2.96**	2.49*	5.72**	.84	1.16
Asc. vs Kena		.22	1.99	4.14**	4.08**	2.14*	2.48*

Generally the only consistent difference which appeared among all treatments and conditions was that of prooxidative effect of sodium chloride, yielding higher TBA numbers. For all conditions and meats (excluding one), TBA numbers of control samples did not significantly differ from initial TBA numbers.

MDTM stored at -18°C three and six months was evaluated raw, raw then cooked, and raw, cooked and held at 4°C to enable evaluation of antioxidant effectiveness and carry through. Stress conditions of cooking and holding after cooking were used to simulate common and extreme prooxidative conditions. The evaluation of the effectiveness of antioxidant treatments under these stresses was made using t statistic comparisons between planned groupings of treatments. Comparisons (Y vs X) were made as (Y-X) and significant differences indicated as positive or negative. Negative t statistics therefore indicated lower TBA numbers for treatments appearing first in the comparison. Generally Type I antioxidants had greater carry through than Type II. EDTA possessed greater carry through than citric acid or ascorbic acid treatments. Kena was generally superior to other Type II antioxidants.

Dramatic increases due to cooking and storage as shown throughout the literature did not occur in this study. The fact that control samples did not increase suggests an overriding untested handling effect. In this study relatively large samples were placed in loaf pans and

vacuum sealed. This procedure was used in an attempt to reduce the oxidative effects due to the greater surface area to volume relationships inherent in "lab" samples compared to commercially packaged MDTM. Though vacuum sealing was not tested in this experiment, it can be theorized that the control samples were stabilized by this handling procedure. TBA mean values obtained for control "light" meat only, air packaged and vacuum sealed in kilogram lots, stored at -18°C 12 months, were 2.70 ± 0.04 and 1.10 ± 0.04 respectively. These limited data support this hypothesis.

Experiment III. Mean values for initial pH of MDTM following mixing stresses are presented in Table 56. Mean pH values decreased for mixing treatments compared to the control. A relatively large decrease in pH was noted for MDTM mixed under carbon dioxide. These data were as anticipated. Mean values of TBA numbers for MDTM held at 4°C after various mixing stresses and packaging conditions are presented in Table 57. Hunter Lab color means for MDTM held under these conditions are presented in Table 58. Analyses of variance of these data are summarized in Table 59.

Significant differences in TBA numbers were shown for mixing and packaging treatments and for holding time. Overall main effect TBA mean values for control, air mix, nitrogen mix, and carbon dioxide mix were 0.68, 0.85, 0.71, and 0.76 respectively. Overall TBA means for packaging

Table 56. Initial pH Values[1] for MDTM after Different Mixing Stresses

	Control (No Mix)	Air Mix	Nitrogen Mix	Carbon Dioxide Mix
pH	$6.14 \pm .02$	$6.08 \pm .01$	$6.10 \pm .00$	$5.76 \pm .02$

[1]Mean values and standard deviations (n=2 direct readings)

Table 57. TBA Numbers[1] for MDTM Held at 4°C after Different Mixing Stresses and Packaging Treatments

	Control (No Mix)		Air Mix		Nitrogen Mix		Carbon Dioxide Mix	
	Air	Vacuum	Air	Vacuum	Air	Vacuum	Air	Vacuum
Days								
1	.83±.06	.73±.04	.78±.08	.82±.08	.58±.03	.69±.04	.72±.03	.60±.04
2	.66±.08	.64±.03	.79±.01	.84±.04	.73±.08	.62±.06	.78±.08	.70±.06
3	.72±.12	.65±.03	.87±.13	.88±.17	.73±.04	.67±.03	.84±.11	.72±.01
4	.49±.03	.58±.00	.82±.12	.79±.17	.60±.08	.75±.18	.77±.11	.57±.01
5	.68±.12	.70±.06	.87±.16	.76±.13	.74±.05	.70±.01	.82±.20	.69±.06
6	.80±.03	.70±.04	.98±.13	.96±.20	.86±.14	.74±.06	1.12±.08	.76±.12

[1]Mean values and standard deviations (2 samples/treatment X 2 distillations/sample X 2 reactions/distillation, n=8)

Table 58. Hunter Lab Color[1] for MDTM Held at 4°C after Different Mixing Stresses and Packaging Treatments

Days	Air Packaged MDTM L	a_L	b_L	Vacuum Packaged MDTM L	a_L	b_L
			Control (No Mix)			
1	58.4±.2	9.3±.6	8.8±.1	56.7±.1	8.8±.1	8.4±.3
2	55.2±.8	9.6±.9	9.7±.8	55.4±.4	8.8±.1	9.0±.6
3	56.2±.2	9.4±.1	9.6±.3	54.8±1.2	9.5±.1	9.0±.1
4	57.8±.6	10.0±.1	9.5±.7	56.4±.4	9.3±.1	9.0±.1
5	55.9±.8	10.2±.8	9.6±.0	54.7±.1	10.2±1.1	9.1±1.0
6	56.2±.0	10.0±.3	9.8±.2	54.6±.1	9.9±.1	9.0±.1
			Air Mix			
1	67.1±.4	12.6±.0	12.4±.3	67.2±.4	12.4±.2	12.2±.8
2	66.8±.8	10.5±1.4	12.2±.4	67.6±.8	10.2±1.4	11.8±.3
3	66.8±.3	8.3±.1	11.9±.4	67.0±1.8	6.8±.6	11.0±.0
4	66.2±1.8	8.0±.6	11.6±.1	66.1±2.7	7.2±1.3	11.1±.4
5	65.6±1.1	8.4±1.1	11.4±1.1	65.0±.6	7.4±.3	10.8±.8
6	65.2±.3	8.0±.3	10.7±.4	65.0±.7	7.6±.4	10.1±.6
			Nitrogen Mix			
1	67.8±.9	8.4±1.1	10.1±.0	67.4±.9	6.7±.4	9.6±.6
2	66.2±.0	8.7±1.8	11.2±.8	66.7±.1	6.8±.1	10.4±.3
3	67.4±.5	7.3±.1	10.0±.3	67.4±.0	7.1±.1	9.8±.0
4	65.8±.5	7.7±.4	10.3±.6	66.4±1.2	7.3±.4	10.2±.2
5	66.8±.0	7.6±.6	11.0±.8	68.0±1.1	7.0±.1	9.6±.1
6	67.1±.4	7.4±.6	10.6±.8	66.0±.3	7.2±.2	10.2±.1
			Carbon Dioxide Mix			
1	58.6±.9	9.9±1.3	9.9±.7	57.9±2.5	9.2±.5	9.2±.4
2	56.8±.1	9.7±.4	9.9±.6	57.2±.3	8.8±.0	9.4±.1
3	57.4±.9	10.1±.0	10.6±.1	56.9±.3	9.2±.4	9.4±.4
4	56.3±.1	9.6±.3	10.2±.1	56.1±.4	9.4±.0	9.4±.1
5	56.4±.1	9.0±.1	10.0±.0	56.7±.8	9.0±.4	9.2±.4
6	56.8±1.1	9.5±.1	10.0±1.1	56.6±.8	9.4±.4	10.2±1.1

[1]Mean values and standard deviations (2 readings at 90°/sample X 2, n=4)

Table 59. Analysis of Variance of TBA Numbers and Hunter Lab Color Values for MDTM Held at 4°C after Different Mixing Stresses and Packaging Treatments

Source of Variation	df	Hunter Lab Measure			
		TBA	L	a_L	b_L
		Mean Squares			
Main Effects	9	.09**	274.84**	10.44**	8.24**
Mixing	3	.13**	813.15**	22.71**	21.49**
Packaging	1	.09**	3.12	8.22**	8.05**
Time	5	.06**	6.21**	3.52**	.32
2-Way	23	.01	1.33	3.26**	.56*
Mixing X Pack.	3	.04**	.77	.29	.01
Mixing X Time	15	.01	1.37	4.83**	.83**
Pack. X Time	5	.01	1.56	.34	.10
3-Way					
Mixing X Pack. X Time	15	.01	.80	.31	.13
Residual	48	.01	1.76	.41	.28
CV(%)		12.65	2.16	7.24	5.20
Mixing	3	.13**	813.15**	22.70**	21.49**
Residual	92	.01	1.76	1.36	.41
		Tukey Separations			
Control		a		a	
Air		b	a	a	
Nitrogen		a	a		a
Carbon Dioxide		ab		a	a

were air, 0.78, and vacuum, 0.72. The significant interaction between mixing and packaging was associated with scattered differences between packaging treatments among control, air mix, and nitrogen mix treatments during the holding time. Lower TBA numbers were obtained from air packaged MDTM than from vacuum sealed MDTM in 39% of the three mixing and six time combinations. MDTM mixed under carbon dioxide had consistently lower TBA numbers during the holding time when vacuum sealed than when packaged in air.

Significant differences were shown for mixing and time for Hunter L values. Overall mean Hunter L values for control, air mix, nitrogen mix, and carbon dioxide mix treatments were 55.7, 66.4, 66.5, and 57.0 respectively. MDTM mixed under air and nitrogen was significantly lighter (increased L values) than that not mixed (control) and that mixed under carbon dioxide. No significant differences in Hunter L values were detected between air and vacuum packaged MDTM.

Significant main effects for Hunter a_L values were detected for mixing, packaging, and holding time. Overall main effect mean values for control, air mix, nitrogen mix, and carbon dioxide mix treatments were 9.6, 9.0, 7.4, and 9.4 respectively. Values for nitrogen mixed MDTM were significantly lower than for all other treatments. Packaging in air (overall mean, 9.1) resulted in significantly higher Hunter a_L values than vacuum packaging

(overall mean, 8.6). The significant mixing by time interaction was associated with high Hunter a_L values for air mixed MDTM in the initial times. These Hunter a_L measures decreased to relatively low values during holding time. This interaction involving air mixing was presumably a result of greater oxygen incorporation during mixing and increased pigment oxidation with holding time. Other treatments exhibited only slight changes in Hunter a_L values throughout the holding time.

Significant main effects for Hunter b_L values were shown for mixing, packaging, and time. Overall means for control, air mix, nitrogen mix, and carbon dioxide mix treatments were 9.2, 11.4, 10.2, and 9.8 respectively. Nitrogen and carbon dioxide mixing did not result in significantly different values from the other treatments. Packaging in air (overall mean, 10.4) resulted in significantly higher Hunter b_L values than packaging under vacuum (overall mean, 9.9). The significant mixing by time interaction for Hunter b_L values was associated with the decreasing trend in air mixed MDTM throughout the six day holding time.

SUMMARY AND CONCLUSIONS

MDTM Substituted Loaf Study

Loaves substituted at 0% through 30% mechanically deboned turkey meat (MDTM) were of greatest commercial interest and therefore, analyzed as a group. Soy substituted and 100% MDTM loaves were included for comparative purposes.

The chemical composition of loaves generally reflected the blend of ingredient meats. The cooked meat yield dramatically increased with increased MDTM substitution. Increased cooked meat yield was attributed to greater fluid retension possibly due to higher pH (increased water holding capacity with increased pH).

Loaf volume and overall linear dimensions increased with increased MDTM substitution. The increase in loaf size was accompanied by slight increases in "loaf distortion."

Objective evaluation of color of cooked slices indicated consistent decreased lightness (grayness), accompanied by increased redness with increased MDTM substitution. Visual examination of slices indicated a darker and more intense red color due to increased MDTM.

Texture evaluation of MDTM substituted loaves performed by slice breaking and shearing indicated reduced binding strength and increased tenderness with increases in MDTM. Reduced binding strength of loaves formulated with MDTM would be anticipated due to the composition, processing stresses, and lack of intact muscle fibers. Increased tenderness with increased MDTM may have been due to lack of muscle fibers, increased moisture retension or the spongy nature of the product.

TBA numbers for foil wrapped loaves held at 4°C one week decreased with increasing levels of MDTM. These results were at variance with those expected and possible explanations were speculative. Two untested explanations are offered with caution. First, during tumble mixing under nitrogen it was observed that the salt extracted meat mixture became stickier and more cohesive with increased levels of mechanically deboned meat. Perhaps the ratio of nitrogen incorporated into loaves increases with increased substitution level. This may appear unlikely since precooked loaves exhibited the same response. Second, a more compositional approach may involve a changing state of iron (Kendrick and Watts, 1969) or lipid and heme relationship, both causing an antioxidant effect with increased MDTM. Precooking significantly increased TBA numbers during holding at 4°C. Changes occurring in precooked loaves were greater than those accounted for by cooking alone. These results were consistent with

anticipated changes. Sensory evaluation did not differentiate substitution levels or cooking treatments.

Raw and precooked foil wrapped and vacuum sealed loaves stored at -18°C for six months showed increased TBA numbers with increased MDTM substitution. Precooked loaves had significantly higher TBA numbers than those stored raw. Foil wrapped loaves had higher TBA numbers than those vacuum sealed. A significant cooking by packaging interaction was associated with vacuum sealing, reducing TBA numbers of precooked loaves to a greater extent than of raw loaves.

Sensory evaluations indicated that loaves were more moist and tender with increased MDTM level. In general, sensory methods did not satisfactorily distinguish flavor differences. Triangle difference tests using 10% MDTM substituted loaves indicated detectable differences in precooked and raw loaves for those both foil and vacuum packaged. Packaging differences were, however, only detected for precooked loaves.

Soy substituted loaves generally possessed reasonable physical characteristics; however, they had high TBA numbers and were judged totally unacceptable due to the objectionable soy isolate flavor.

Physical characteristics of all loaves were acceptable with no major functional problems associated with MDTM substitution. The loaves prepared at 0% through 30% MDTM substitution levels were of high quality even after

storage at -18°C six months. Vacuum packaging was more effective than foil wrapping and raw storage was more effective than precooking in maintenance of high quality MDTM substituted products.

In Vivo Tocopherol Supplementation Study

Significant differences in dressing and hand boning operations were associated with sex. Compositional differences in turkey meat were associated with sex and meat type and not with tocopherol treatment. These data were consistent with expected differences due to sex and meat type of turkey.

Tocopherol supplementation reduced TBA numbers in meat and loaves held at 4°C and stored at -18°C compared to controls. Females had lower TBA numbers than males for breast, thigh, and MDTM. Thigh meat had higher TBA numbers than MDTM and breast meat. Breast meat had the lowest TBA numbers. Tocopherol supplemented breast and MDTM used in loaf formulations resulted in lower TBA numbers than control loaves after holding at 4°C one week. Vacuum packaging further reduced TBA numbers under these conditions. TBA numbers for meat from females were lower than those for meat from males. Loaves stored at -18°C three and six months responded in a similar manner.

In general, tocopherol treatments yielded lower TBA numbers than control for meat items and loaves. Vacuum sealing was superior to foil wrapping, and cooking

resulted in increased TBA numbers for loaves. Meat obtained from females had lower TBA numbers than that obtained from males.

MDTM Stability Study

A summary of the proximate composition of all samples used in these studies is shown in Table 60. Greatest variation was due to fluctuating moisture and fat percents.

Table 60. Summary of Proximate Composition[1] of MDTM Used in All Studies

Moisture %	Fat %	Protein %	Ash %	Ca++ %
70.6±2.5	12.88±3.07	14.0±.9	1.11±.03	.167±.021

[1]Mean values and standard deviations (n=6 separate lots)

Experiment I. Tenox 2 was more effective than EDTA in stabilizing TBA during holding at 4°C and particularly during storage at -18°C. No synergistic activity was shown between EDTA and Tenox 2. Tenox 2 treated samples maintained TBA numbers of less than 0.5 after storage at -18°C six months.

Experiment II. "Dark" MDTM had significantly higher TBA numbers than did "light" MDTM initially, after holding at 4°C one week, and during storage at -18°C up to six months.

Type I antioxidants were generally more effective than Type II, particularly after cooking and holding cooked meat at 4°C one week. Of Type II antioxidants, Kena was more effective than EDTA, citric acid, or ascorbic acid. The TBA production throughout this experiment was lower than expected and may have been due to overriding effects of vacuum packaging.

Experiment III. Mixing mechanically deboned meat resulted in higher TBA numbers than control (no mixing) during holding at 4°C up to six days. Mixing in air resulted in the highest TBA numbers, presumably due to greater incorporation of oxygen. Mixing under both nitrogen and carbon dioxide lowered TBA numbers. Overall TBA values were higher in air packaged MDTM than in those vacuum sealed.

Air and nitrogen mixed samples were lighter (increased Hunter L) in color than control or carbon dioxide mixed MDTM. Air and nitrogen mixed MDTM were lighter, possibly due to gas incorporation (foaming). The lower pH may have accounted for the darker color of the carbon dioxide mixed MDTM. Pigment oxygenation was noted in air mixed samples.

This experiment illustrated the prooxidant effects that may be expected from mixing. This may have implications for commercial handling of MDTM.

Overview

Data presented in these studies indicated that lipid oxidation, as evaluated by the TBA test, increased with cooking, precooking, and time; and decreased with tocopherol supplementation and vacuum packaging.

A general statement, though not directly tested, would appear to indicate that MDTM can be utilized in the formulation of high quality products, and with the proper handling and distribution, quality deterioration minimized.

RECOMMENDATIONS FOR FURTHER RESEARCH

1. Evaluation of vacuum packaging (partial pressure of oxygen) on the rate of lipid oxidation of MDTM; design experiments in a manner similar to those of Janky and Froning (1975).

2. In plant evaluation of vacuum packaging MDTM in commercial size containers either by direct vacuum sealing or perhaps more effectively by deaeration of MDTM under vacuum and released with nitrogen prior to packaging.

3. Evaluation of the effect of refrigerated holding of MDTM prior to product formulation and subsequent freezing. Present regulations permit holding at $40^{\circ}F$ ($4.4^{\circ}C$) up to three days prior to product formulation. What effect will this induction period have on storage stability of final product?

4. Evaluation of the storage stability of loaves formulated with breast and thigh meats and MDTM.

APPENDIX

APPENDIX

Table 61. Composition of Turkey Diets[1] Used in Tocopherol Supplementation Study

Ingredient	Starter %	Grower %
ground yellow corn	42.70	58.90
soybean, 49% protein	41.10	29.80
alfalfa meal, 17% protein	3.00	2.50
fish meal, 49% protein	3.00	---
meat+bone meal, 50% protein	3.00	3.50
whey, dried	2.50	---
fat, AV	1.50	2.50
dicalcium phosphate	.25	.25
ground limestone	1.50	1.25
salt	1.25	.75
Vitamin-Mineral Premix[2]	.75	.60
biotin	---	.01
<u>Calculated Analysis</u>		
crude protein	28.00	22.00
fat	3.89	5.22
fiber	3.29	3.25
calcium	1.40	1.00
phosphorous, avail.	.67	.55
Kcal. M.E./kg diet	2778.6	3040.4

[1]Starter fed zero to eight weeks of age; grower fed eight weeks through slaughter

[2]Composition outlined in Table 62

Table 62. Composition of Vitamin-Mineral Premix Used in Turkey Diets[1] in Toccpherol Supplementation Study

Nutrient	supplied/kg premix	Starter supplied/kg diet	Grower supplied/kg diet
Vitamin A (U.S.P. Units)	1320000.0	9900.0	7920.0
Vitamin D_3 (I.C. Units)	366667.0	2750.0	2200.0
Riboflavin (mg)	880.0	6.6	5.28
Thiamine Mononitrate (mg)	148.0	1.11	.89
Pantothenic Acid (mg)	1760.0	13.2	10.56
Niacin (mg)	7335.0	55.01	44.01
Choline Chloride (mg)	90935.0	682.01	545.61
Vitamin B_{12} (mg)	2.2	.016	.013
Menadione Na Bisulfite (mg)	293.0	2.20	1.76
Vitamin E (I.U.)	1100.0	8.25	6.6
Folic Acid (mg)	257.0	1.93	1.54
Methionine Hydroxy Analogue Calcium (g)	22.0	.16	.132
Manganese (g)	19.93	.15	.12
Iodine (mg)	200.0	1.50	1.2
Copper (mg)	164.0	1.23	.984
Cobalt (mg)	5.0	.04	.03

[1]Nutrients expressed per kilogram premix and as supplied per kilogram of diet

LIST OF REFERENCES

LIST OF REFERENCES

Ackman, R.G. 1976. Prediction of fat stability. Round Table Discussions, Session III, chrm. Dugan, L., Jr. In "Proceedings of a Symposium: Objective Methods for Food Evaluation," p. 272. National Academy of Sciences, Washington, D.C.

Acosta, S.O., Marion, W.W., and Forsythe, R.H. 1966. Total lipids and phospholipids in turkey tissue. Poultry Sci. 45:169.

Acton, J.C. 1972. Effect of heat processing on extractability of salt-soluble protein, tissue binding strength and cooking loss in poultry meat loaves. J. Food Sci. 37:244.

Acton, J.C. 1973. Composition and properties of extruded, texturized poultry meat. J. Food Sci. 38:571.

Amerine, M.A., Pangborn, R.M., and Roessler, E.B. 1965. "Principles of Sensory Evaluation of Food." Academic Press, New York.

Angel, S., Darfler, J.M., Hood, L.F., and Baker, R.C. 1974. Frankfurters made from mechanically deboned poultry meat (MDPM) 2. Microscopy. Poultry Sci. 53: 166.

Anonymous. 1970. Improving the keeping qualities of meat and poultry products with Tenox antioxidants. Pub. No. ZG-183. Eastman Chemical Products, Inc., Kingsport, Tennessee.

Anonymous. 1976a. Poultry and egg situation 291. Economic Research Service, U.S.D.A., Washington, D.C.

Anonymous. 1976b. Tenox food-grade antioxidants. Pub. No. ZG-109B. Eastman Chemical Products, Inc., Kingsport, Tennessee.

A.O.A.C. 1975. "Official Methods of Analysis," 12th ed. Association of Official Agricultural Chemists, Washington, D.C.

Baker, R.C. 1976. Urgent! New poultry products needed. Broiler Industry 39:18.

Baker, R.C. and Darfler, J.M. 1975. Acceptability of frankfurters made from mechanically deboned turkey frames as affected by formulation changes. Poultry Sci. 54:1283.

Baker, R.C., Darfler, J.M., and Angel, S. 1974. Frankfurters made from mechanically deboned poultry meat (MDPM) 1. Effect of chopping time. Poultry Sci. 53: 156.

Baker, R.C., Darfler, J.M., and Vadehra, D.V. 1972. Effect of selective additives on the acceptability of chicken frankfurters. Poultry Sci. 51:1616.

Ball, C.O. 1967. Flexible packaging in food processing. In "Fundamentals of Food Processing Operations," eds. Heid, J.L. and Joslyn, M.A., p. 669. The AVI Publishing Company, Inc., Westport, Connecticut.

Benedict, R.C., Strange, E.D., and Swift, C.E. 1975. Effect of lipid antioxidants on the stability of meat during storage. J. Agr. Food Chem. 23:167.

Bowers, J.A. 1972. Eating quality, sulfhydryl content, and TBA values of turkey breast muscle. J. Agr. Food Chem. 20:706.

Bowers, J.A., Goertz, G.E., and Fry, J.L. 1965. Effect of cooking method and skewers on quality of turkey rolls. Poultry Sci. 44:789.

Branen, A.L. 1975. Toxicology and biochemistry of butylated hydroxyanisole and butylated hydroxytoluene. J. Amer. Oil Chem. Soc. 52:59.

Bratzler, L.J. 1971. Palatability factors and evaluation. In "The Science of Meat and Meat Products," eds. Price, J.F. and Schweigert, B.S., p. 328. W.H. Freeman and Co., San Francisco.

Brekke, C.J., Al-Hakim, S.H., Highlands, M.E., and Hogan, J.M. 1975. The relation of in vivo and in vitro tocopherol supplementation to stability of fowl fat. Poultry Sci. 54:2019.

Cash, D.B. and Carlin, A.F. 1968. Quality of frozen boneless turkey roasts precooked to different internal temperatures. Food Technol. 22:1477.

Cipra, J.S. and Bowers, J.A. 1970. Precooked turkey. Flavor and certain changes caused by refrigeration and reheating. Food Technol. 24:921.

Cort, W.M. 1974. Antioxidant activity of tocopherols, ascorbyl palmitate, and ascorbic acid and their mode of action. J. Amer. Oil Chem. Soc. 51:321.

Cunningham, F.E. 1975. Acceptability and use of frozen poultry--a review. World's Poultry Sci. J. 31:136.

Cunningham, F.E. and Froning, G.W. 1972. A review of factors affecting emulsifying characteristics of poultry meat. Poultry Sci. 51:1714.

Cunningham, F.E. and Mugler, D.J. 1973. Stability of cooked chicken wieners during frozen storage. Poultry Sci. 52:931.

Cunningham, F.E. and Mugler, D.J. 1974. Deboned fowl meat offers opportunities. Poultry Meat 25:46.

Dawson, L.E. 1969. Stability of frozen poultry meat and eggs. In "Quality and Stability in Frozen Foods," eds. VanArsdel, W.B., Copley, M.J., and Olson, R.L., p. 143. Wiley-Interscience, New York.

Dawson, L.E. 1975. Utilization of mechanically deboned meat from turkeys. In Proc. 2nd European Symp. on Poultry Meat Quality. Oosterbeek, The Netherlands, May 12-15.

Dawson, L.E. and Schierholz, K. 1976. Influence of grinding, cooking and refrigerated storage on lipid stability in turkey. Poultry Sci. 55:618.

Dawson, L.E., Stevenson, K.E., and Gertonson, E. 1975. Flavor, bacterial and TBA changes in ground turkey patties treated with antioxidants. Poultry Sci. 54: 1134.

Day, E.A. 1966. Autoxidation of milk lipids. J. Dairy Sci. 43:1360.

Deman, J.M. and Melnychyn, P., eds. 1971. "Symposium: Phosphates in Food Processing." The AVI Publishing Company, Inc., Westport, Connecticut.

Dhillon, A.S. and Maurer, A.J. 1975a. Quality measurements of chicken and turkey summer sausages. Poultry Sci. 54:1263.

Dhillon, A.S. and Maurer, A.J. 1975b. Stability study of comminuted poultry meats in frozen storage. Poultry Sci. 54:1407.

Dhillon, A.S. and Maurer, A.J. 1975c. Utilization of mechanically deboned chicken meat in the formulation of summer sausages. Poultry Sci. 54:1164.

Dimick, P.S. and MacNeil, J.H. 1970. Poultry product quality. 2. Storage time-temperature effects on carbonyl composition of cooked turkey and chicken skin fractions. J. Food Sci. 35:186.

Dimick, P.S., MacNeil, J.H., and Grunden, L.P. 1972. Poultry product quality. Carbonyl composition and organoleptic evaluation of mechanically deboned poultry meat. J. Food Sci. 37:544.

Dugan, L., Jr. 1960. Antioxidants that protect your fats and foods made with your fats. Circ. 63, Amer. Meat Inst. Foundation, Chicago, Illinois.

Dugan, L., Jr. 1961. Development and inhibition of oxidative rancidity in foods. Food Technol. 15:160.

Dugan, L., Jr. 1968. Processing and other stress effects on the nutritive value of lipids. World Rev. Nutr. Diet. 9:181.

Dugan, L., Jr. 1976. Prediction of fat stability. Round Table Discussions, Session III. In "Proceedings of a Symposium: Objective Methods for Food Evaluation," p. 265. National Academy of Sciences, Washington, D.C.

Erickson, D.R. and Bowers, R.H. 1976. Objective determination of fat stability in prepared foods. Technical Session II, chrm. Olcott, H.S. In "Proceedings of a Symposium: Objective Methods for Food Evaluation," p. 133. National Academy of Sciences, Washington, D.C.

Essary, E.O. and Ritchey, S.J. 1968. Amino acid composition of meat removed from boned turkey carcasses by use of commercial boning machine. Poultry Sci. 47: 1953.

Essary, E.O. and Rogers, P.J. 1968. Effects of holding conditions on the cooking time and loss, and organoleptic values of turkey rolls. Poultry Sci. 47:1670.

Field, R.A. 1976. Mechanically-deboned red meat. Food Technol. 30:38.

Field, R.A., Riley, M.L., Mello, F.C., Corbridge, M.H., and Kotula, A.W. 1974. Bone composition in cattle, pigs, sheep, and poultry. J. Anim. Sci. 39:493.

Froning, G.W. 1965. Effect of polyphosphates on binding properties of chicken meat. Poultry Sci. 44:1104.

Froning, G.W. 1966. Effect of various additives on the binding properties of chicken meat. Poultry Sci. 45:185.

Froning, G.W. 1970. Poultry meat sources and their emulsifying characteristics as related to processing variables. Poultry Sci. 49:1625.

Froning, G.W. 1973. Effect of chilling in the presence of polyphosphates on the characteristics of mechanically deboned fowl meat. Poultry Sci. 52:920.

Froning, G.W. 1976. Mechanically-deboned poultry meat. Food Technol. 30:50.

Froning, G.W., Arnold, R.G., Mandigo, R.W., Neth, C.E., and Hartung, T.E. 1971. Quality and storage stability of frankfurters containing 15% mechanically deboned turkey meat. J. Food Sci. 36:974.

Froning, G.W. and Janky, D.M. 1971. Effect of pH and salt preblending on emulsifying characteristics of mechanically deboned turkey frame meat. Poultry Sci. 50:1206.

Froning, G.W. and Johnson, F. 1973. Improving the quality of mechanically deboned fowl meat by centrifugation. J. Food Sci. 38:279.

Furia,T.E. 1964. EDTA in Foods. Food Technol. 50:1874.

Goodwin, T.L., Bramblett, V.D., Vail, G.E., and Stadelman, W.J. 1962. Effects of end-point temperature and cooking rate on turkey meat tenderness. Food Technol. 16:101.

Goodwin, T.L., Webb, J.E., Trent, C.M., and Reames, C.E. 1968. Chemical composition of mechanically deboned chicken. Poultry Sci. 47:1674.

Greene, B.E. and Price, L.G. 1975. Oxidation-induced color and flavor changes in meat. J. Agr. Food Chem. 23:164.

Grunden, L.P., MacNeil, J.H., and Dimick, P.S. 1972. Poultry product quality: chemical and physical characteristics of mechanically deboned poultry meat. J. Food Sci. 37:247.

Hartung, T.E. and Froning, G.W. 1967. Lipid stability as influenced by strain, sex and age of turkey. Poultry Sci. 46:1270.

Hayse, P.L., Marion, W.W., and Paulson, R.J. 1974. The effectiveness of tocopherol in controlling oxidative rancidity in turkey. Poultry Sci. 53:1934.

Helmke, A. and Froning, G.W. 1971. The effect of end-point cooking temperature and storage on the color of turkey meat. Poultry Sci. 50:1832.

Hoke, I.M., McGeary, B.K., and Kleve, M.K. 1967. Effect of internal and oven temperatures on eating quality of light and dark meat turkey roasts. Food Technol. 21:773.

Hooper, A.S., Goertz, G.E., and Mitchell, J.D. 1965. Acceptability, cooking losses and microbial quality of stored uncooked and precooked turkey rolls. Poultry Sci. 44:1381.

Ingold, K.U. 1962. Metal catalysis. In "Symposium on Foods: Lipids and Their Oxidation," ed. Schultz, H.W., p. 93. The AVI Publishing Company, Inc., Westport, Connecticut.

Ingold, K.U. 1968. Principles of metal catalysed (sic) lipid oxidation. In "Metal Catalysed Lipid Oxidation," ed. Marcuse, R., p. 11. SIK, Göteborg, Sweden. SIK-Rapport nr 240.

Jacobson, M. and Koehler, H.H. 1970. Development of rancidity during short-time storage of cooked poultry meat. J. Agr. Food Chem. 18:1069.

Janky, D.M. and Froning, G.W. 1973. The effect of pH and certain additives on heat denaturation of turkey meat myoglobin. Poultry Sci. 52:152.

Janky, D.M. and Froning, G.W. 1975. Factors affecting chemical properties of heme and lipid components in mechanically deboned turkey meat. Poultry Sci. 54:1378.

Johnson, P.G. and Bowers, J.A. 1974a. Freshly cooked reheated turkey breast muscle. 1. Cooking losses and sensory evaluation of muscle and expressed juice. Poultry Sci. 53:343.

Johnson, P.G. and Bowers, J.A. 1974b. Freshly cooked and reheated turkey breast muscle. 2. Physical and chemical characteristics of muscle and expressed juice. Poultry Sci. 53:349.

Johnson, P.G., Cunningham, F.E., and Bowers, J.A. 1974. Quality of mechanically deboned turkey meat: effect of storage time and temperature. Poultry Sci. 53:732.

Kendrick, J. and Watts, B.M. 1969. Acceleration and inhibition of lipid oxidation by heme compounds. Lipids 4:454.

Keskinel, A., Ayres, J.C., and Snyder, H.E. 1964. Determination of oxidative changes in raw meats by the 2-thiobarbituric acid method. Food Technol. 18:223.

Kinsella, J.E., Posati, L., Weihrauch, J., and Anderson, B. 1975. Lipids in foods: problems and procedures in collating data. Crit. Rev. Food Technol. 5:299.

Klinger, S.D. and Stadelman, W.J. 1975. Flavor of reheated roast duck. Poultry Sci. 54:1278.

Labuza, T.P. 1971. Kinetics of lipid oxidation in foods. Crit. Rev. Food Technol. 2:355.

Lea, C.H. 1962. The oxidative deterioration of food lipids. In "Symposium on Foods: Lipids and Their Oxidation," ed. Schultz, H.W., p. 3. The AVI Publishing Company, Inc., Westport, Connecticut.

Lee, Y.B., Hargus, G.L., Kirkpatrick, J.A., Berner, D.L., and Forsythe, R.H. 1975. Mechanism of lipid oxidation in mechanically deboned chicken meat. J. Food Sci. 40: 964.

Little, T.M. and Hills, F.J. 1972. Some basic concepts. In "Statistical Methods in Agricultural Research," p. 13. Agricultural Extension, U. of California, Berkeley, California.

Love, J.D. and Pearson, A.M. 1971. Lipid oxidation in meat and meat products--a review. J. Amer. Oil Chem. Soc. 48:547.

Lund, D.B., Lindsay, R.C., and Branen, A.L. 1976. Comparison of methods for introduction of antioxidants into food systems. Presented 36th Annual Meeting of the Institute of Food Technologists, Anaheim, California, June 6-9. Abstract No. 183.

MacNeil, J.H. and Dimick, P.S. 1970a. Poultry product quality. 1. Compositional changes during cooking of turkey roasts. J. Food Sci. 35:184.

MacNeil, J.H. and Dimick, P.S. 1970b. Poultry product quality. 3. Organoleptic evaluation of cooked chicken and turkey skin fractions as affected by storage time and temperature. J. Food Sci. 35:191.

MacNeil, J.H., Dimick, P.S., and Mast, M.G. 1973. Use of chemical compounds and a rosemary spice extract in quality maintenance of deboned poultry meat. J. Food Sci. 38:1080.

Maesso, E.R., Baker, R.C., Bourne, M.C., and Vadehra, D.V. 1970. Effect of some physical and chemical treatments on the binding quality of poultry loaves. J. Food Sci. 35:440.

Maesso, E.R., Baker, R.C., and Vadehra, D.V. 1970. The effect of vacuum, pressure, pH and different meat types on the binding ability of poultry meat. Poultry Sci. 49:697.

Marcuse, R. and Johansson, L. 1973. Studies on the TBA test for rancidity grading: II. TBA reactivity of different aldehyde classes. J. Amer. Oil Chem. Soc. 50: 387.

Marion, W.W. and Forsythe, R.H. 1964. Autoxidation of turkey lipids. J. Food Sci. 29:530.

Marquess, C.G., Carlin, A.F., and Augustine, G.N. 1963. Factors affecting the quality of roasted turkey rolls. Food Technol. 17:110.

Martin, R.E. 1974. "Commercially Available Equipment." Second Technical Seminar on Mechanical Recovery and Utilization of Fish Flesh, Boston, MA. June 12-13. National Fisheries Institute, Washington, D.C.

Martinson, C.S. and Carlin, A.F. 1968. Rate of heating during precooking in foil and quality of boneless turkey roasts stored at 0°F. Food Technol. 22:223.

Marusich, W.L., DeRitter, E., Ogrinz, E.F., Keating, J., Mitrovic, M., and Bunnell, R.H. 1975. Effect of supplemental Vitamin E in control of rancidity in poultry meat. Poultry Sci. 54:831.

Maurer, A.J. 1973. Emulsifying characteristics of mechanically and hand deboned poultry meat mixtures. Poultry Sci. 52:2061.

Maxon, S.T. and Marion, W.W. 1970. Lipids of mechanically boned turkey. Poultry Sci. 49:1412.

McMahon, E.F. and Dawson, L.E. 1976a. Influence of mechanically deboned meat and phosphate salts on functional and sensory attributes of fermented turkey sausage. Poultry Sci. 55:103.

McMahon, E.F. and Dawson, L.E. 1976b. Effects of salt and phosphates on some functional characteristics of hand and mechanically deboned turkey meat. Poultry Sci. 55:573.

Mecchi, E.P., Pool, M.F., Behman, G.A., Hamachi, M., and Klose, A.A. 1956a. The role of tocopherol content in the comparative stability of chicken and turkey fat. Poultry Sci. 35:1238.

Mecchi, E.P., Pool, M.F., and Klose, A.A. 1953. The role of tocopherol content in the stability of chicken and turkey fats. Poultry Sci. 32:915.

Mecchi, E.P., Pool, M.F., Nonaka, M., Klose, A.A., Marsden, S.J., and Lillie, R.J. 1956b. Further studies on tocopherol content and stability of carcass fat of chickens and turkeys. Poultry Sci. 35:1246.

Mello, F.C., Jr., Field, R.A., Froenza, S., and Kunsman, J.E. 1976. Lipid characterization of bovine bone marrow. J. Food Sci. 41:226.

Meyer, L.H. 1975. Meat and meat products. In "Food Chemistry," p. 171. The AVI Publishing Company, Inc., Westport, Connecticut.

Moerck, K.E. and Ball, H.R., Jr. 1973. Lipids and fatty acids of chicken bone marrow. J. Food Sci. 38:978.

Moerck, K.E. and Ball, H.R., Jr. 1974. Lipid autoxidation in mechanically deboned chicken meat. J. Food Sci. 39: 876.

Nickerson, J.T. 1967. Preservatives and antioxidants. In "Fundamentals of Food Processing Operations," eds. Heid, J.L. and Joslyn, M.A., p. 209. The AVI Publishing Company, Inc., Westport, Connecticut.

Nie, N.H., Hull, C.H., Jenkins, J.G., Steinbrenner, K., and Bent, D.H. 1975. "Statistical Package for the Social Sciences." McGraw-Hill, Inc., New York.

Palmer, H.H. and Bowers, J. 1972. Poultry and fish. In "Food Theory and Applications," eds. Paul, P.C. and Palmer, H.H., p. 495. John Wiley and Sons, Inc., New York.

Patron, A. 1968. Oxidation through metal catalysis and flavour (sic) stability of foods containing animal fats. In "Metal Catalysed Lipid Oxidation," ed. Marcuse, R., p. 171. SIK, Göteborg, Sweden. SIK-Rapport nr 240.

Patton, S. 1974. Malonaldehyde, lipid oxidation, and the thiobarbituric acid test. J. Amer. Oil Chem. Soc. 51(3):114.

Paul, P.C. 1972. Meat. In "Food Theory and Applications," eds. Paul, P.C. and Palmer, H.H., p. 335. John Wiley and Sons, Inc., New York.

Pepper, F.H. and Schmidt, G.R. 1975. Effect of blending time, salt, phosphate and hot-boned beef on binding strength and cook yield of beef rolls. J. Food Sci. 40: 227.

Pokorny, J. 1971. Stabilization of fats by phenolic antioxidants. Can. Inst. Food Technol. J. 4:68.

Rohlf, F.J. and Sokal, R.R. 1969. "Statistical Tables." W.H. Freeman and Co., San Francisco, California.

Sato, K. and Herring, H.K. 1973. The Chemistry of warmed-over flavor in cooked meats. In "Proc. of 26th Annual Reciprocal Meat Conference of the Amer. Meat Sci. Ass. The Pennsylvania State Univ., University Park, Pennsylvania, June 17-20.

Satterlee, L.D., Froning, G.W., and Janky, D.M. 1971. Influence of skin content on composition of mechanically deboned poultry meat. J. Food Sci. 36:979.

Schnell, P. 1972. Chemical and physical properties of mechanically deboned poultry meat. Ph.D. thesis, Cornell University, Ithaca, New York.

Schnell, P., Vadehra, D.V., Hood, L.R., and Baker, R.C. 1974. Ultrastructure of mechanically deboned poultry meat. Poultry Sci. 53:416.

Schultz, H.W., Day, E.A., and Sinnhuber, R.O. 1962. "Symposium on Foods: Lipids and Their Oxidation." The AVI Publishing Company, Inc., Westport, Connecticut.

Scott, G. 1965. "Atmospheric Oxidation and Antioxidants." Elsevier Publishing Company, New York.

Scott, M.L. 1958. Composition of turkey meat. J. Amer. Diet. Ass. 34:154.

Sherwin, E.R. 1968. Methods for stability and anti-oxidant measurement. J. Amer. Oil Chem. Soc. 45:632A.

Shults, G.W. and Wierbicki, E. 1973. Effects of sodium chloride and condensed phosphates on the water-holding capacity, pH and swelling of chicken muscle. J. Food Sci. 38:991.

Sinnhuber, R.O., Yu, R.C., and Yui, T.C. 1958. Characterization of the red pigment formed in the 2-thiobarbituric acid determination of oxidative rancidity. Food Res. 23:626.

Smith, M.L. and Bowers, J.A. 1972. Effects of a polyphosphate salt on eating quality of precooked-reheated and freshly cooked turkey roulades stored 4 and 8 weeks. Poultry Sci. 51:998.

Stadelman, W.J. 1974. Turkey meat--how long will it keep? In "Proc. of Technology for Convenience, Quality and Value," Activities Report, Vol 2, Chicago, Illinois.

Steagall, E.F. 1966. EDTA titration of calcium and magnesium. J. Ass. Offic. Anal. Chem. 49:287.

Stuckey, B.N. 1962. Antioxidants. In "Symposium on Foods: Lipids and Their Oxidation," ed. Schultz, H.W., p. 139. The AVI Publishing Company, Inc., Westport, Connecticut.

Stuckey, B.N. 1968. Antioxidants as food stabilizers. In "Handbook of Food Additives," ed. Furia, T.E., p. 209. Chemical Rubber Co., Cleveland, Ohio.

Swisher, H.E. and Swisher, L.H. 1967. Use of acids in food processing. In "Fundamentals of Food Processing Operations," eds. Heid, J.L. and Joslyn, M.A., p. 130. The AVI Publishing Company, Inc., Westport, Connecticut.

Tarladgis, B.G., Pearson, A.M., and Dugan, L., Jr. 1962. The chemistry of the 2-thiobarbituric acid test for the determination of oxidative rancidity in foods. I. Some important side reactions. J. Amer. Oil Chem. Soc. 39:34.

Tarladgis, B.G., Pearson, A.M., and Dugan, L., Jr. 1964. Chemistry of the 2-thiobarbituric acid test for determination of oxidative rancidity in foods. II. Formation of the TBA-malonaldehyde complex without acid-heat treatment. J. Sci. Food Agr. 15:602.

Tarladgis, B.G., Watts, B.M., Younathan, M.T., and Dugan, L., Jr. 1960. A distillation method for the quantitative determination of malonaldehyde in rancid foods. J. Amer. Oil Chem. Soc. 37:44.

Taylor, M.H., Smith, L.T., and Mitchell, J.D. 1965. The effect of packaging materials and a tripolyphosphate (Kena) on the shelf-life of turkey steaks. Poultry Sci. 44:297.

Turner, E.W., Paynter, W.D., Montie, E.J., Bessert, M.W., Struck, G.M., and Olson, F.C. 1954. Use of the 2-thiobarbituric acid reagent to measure rancidity in frozen pork. Food Technol. 8:326.

Vadehra, D.V. and Baker, R.C. 1970a. The mechanism of heat initiated binding of poultry meat. Food Technol. 24:766.

Vadehra, D.V. and Baker, R.C. 1970b. Physical and chemical properties of mechanically deboned poultry meat. Poultry Sci. 49:1446.

Vadehra, D.V., Schnell, P.G., and Baker, R.C. 1970. Effect of enzymes, muscle proteins and temperature on the binding ability of poultry meat. Poultry Sci. 49: 1447.

Wangen, R.M., Marion, W.W., and Hotchkiss, D.K. 1971. Influence of age on total lipids and phospholipids of turkey muscle. J. Food Sci. 36:560.

Wardlaw, F.B., McCaskill, L.H., and Acton, J.C. 1973. Effect of postmortem muscle changes on poultry meat loaf properties. J. Food Sci. 38:421.

Waters, W.A. 1971. The kinetics and mechanism of metal-catalyzed autoxidation. J. Amer. Oil Chem. Soc. 48:427.

Watts, B.M. 1962. Meat products. In "Symposium on Foods: Lipids and Their Oxidation," ed. Schultz, H.W., p. 202. The AVI Publishing Company, Inc., Westport, Connecticut.

Webb, R.W., Marion, W.W., and Hayse, P.L. 1972a. Effect of tocopherol supplementation on the quality of precooked and mechanically deboned turkey meat. J. Food Sci. 37:853.

Webb, R.W., Marion, W.W., and Hayse, P.L. 1972b. Tocopherol supplementation and lipid stability in the turkey. J. Food Sci. 37:496.

Wilkinson, R.J. and Dawson, L.E. 1967. Tenderness and juiciness of turkey roasts cooked to different temperatures. Poultry Sci. 46:15.

Witting, L.A. 1975. Vitamin E as a food additive. J. Amer. Oil Chem. Soc. 52:64.

Young, L.L. and Lyon, B.G. 1973. The use of heat treated meat in chicken frankfurters. Poultry Sci. 52:1868.

Yu, T.C. and Sinnhuber, R.O. 1962. Removal of interfering pigments in determining malonaldehyde by the 2-thiobarbituric acid reaction. Food Technol. 16:115.