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Thermal Characteristics of Ground *Pectoralis Secundus* Turkey Muscle

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I am submitting herewith a thesis written by Connie Lynn Lazure entitled "Thermal Characteristics of Ground *Pectoralis Secundus* Turkey Muscle." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Science and Technology.

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To the Graduate Council:

I am submitting herewith a thesis written by Connie Lynn Lazure entitled "Thermal Characteristics of Ground *Pectoralis Secundus* Turkey Muscle." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Food Science.

Grayce E. Goertz
Major Professor

We have read this thesis and
recommend its acceptance:

Ada Marie Campbell

J. L. Collins

Accepted for the Council:

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Vice Chancellor for
Graduate Studies and Research

THERMAL CHARACTERISTICS OF GROUND *PECTORALIS SECUNDUS* TURKEY MUSCLE

A Thesis
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

by
Connie Lynn Lazure
August 1972

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ABSTRACT

Thermal conductivity and diffusivity of ground turkey pectoralis secundus muscle were investigated using a line-source apparatus modified to allow determinations upon the sample during transient heating. Samples (51.5g) were heated in a water jacketed cylinder at and to end points of 77, 95, 113, 131, 149, 167, and 185°F and subjected to holding times of 0 or 15 min. The relationship between thermal properties and moisture factors including total moisture, cooking loss, and expressible moisture index was investigated.

Thermal conductivity values were similar for samples heated at and to temperatures between 77 and 167°F but tended to decrease for those at 185°F. Holding times did not affect thermal conductivity values. There tended to be close agreement among values for a given end point and these were within ranges reported in the literature.

Total moisture gradually decreased for turkey heated to temperatures that ranged from 77 to 149°F. Thereafter a pronounced decrease in total moisture occurred as end points increased. A significant increase in cooking loss was noted between samples heated to 77 and 95°F ($P < 0.001$), to 113 and 131°F or 149°F ($P < 0.01$), and to $149 < 167 < 185$°F ($P < 0.05$). Expressible moisture indexes for 77 and 95°F samples were similar and decreased slightly at 113°F. A pronounced decrease occurred for samples at 131°F. With further increase in temperature, little difference was observed. Expressible moisture indexes were similar for the 149, 167, and 185°F end points. Holding time had little if any effect on all parameters measured.

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CHAPTER I

INTRODUCTION

Thermal conductivity is an important characteristic of meat. Its determination is essential for analytical studies of transient processes in which meat is heated, cooled, or dehydrated. An increased understanding of thermal characteristics should assist in the needed refinements for recommendations for rate and end points of heating of meat for use in food service operations as well as for in the home. Also, engineering design of food processing equipment has been hampered by a lack of fundamental information of the thermal characteristics of food.

The thermal properties of a food are referred to by Dickerson and Read (1968) as the mode of action of heat distribution. Thermal conductivity and diffusivity are the properties that are discussed in the literature. The former establishes heat flow at the food boundary; whereas, the latter serves as a measurement of the quantity of heat absorbed by a food at a given temperature.

Most investigators agree that thermal characteristics are dependent upon temperature. In fact, calculation of these, especially thermal conductivity, requires temperature data (Lentz, 1961; Miller and Sunderland, 1963; Hill *et al.*, 1967).

From the literature, it can be seen that most research to determine thermal conductivity values has been done on meat in a steady state or quasi-steady state condition. Therefore, research in which transient heating is used would be valuable in that it would contribute additional information concerning thermal characteristics of meat. There also is a need for basic information to assist in more accurate determination of end points and their meaning in assessing the degree of doneness of meat. For these reasons, the purpose of this research was to study thermal conductivity and diffusivity of ground turkey *pectoralis secundus* muscle using a line-source apparatus modified to allow determinations upon the sample during transient heating.

The ability of meat to retain moisture during cooking is an important property of muscle. Protein holds water chemically and physically within muscle. Factors which affect the chemical and physical composition of protein also affect water in ways that alter the juiciness, tenderness, and overall acceptability of meat. Heating meat denatures protein and decreases the ability of muscle to retain water (Hamm, 1966). Working with tube-cooked beef, Wierbicki *et al.* (1957) noted that heat denaturation of muscle protein begins at 40°C and essentially is completed at 70°C.

Heat-induced changes in proteins result in shrinkage of tissue and release of juice (Hamm, 1966). Because various investigators have reported changes in water-holding capacity with changes in temperature (Hamm, 1960; Sanderson and Vail, 1963; Rogers *et al.*, 1967), a secondary objective of this study was to relate thermal characteristics of ground *pectoralis secundus* turkey muscle to its ability to bind water.

CHAPTER II

REVIEW OF LITERATURE

Heat Transfer in Foods

Heat transfer is the transmission of energy from one region to another due to a temperature differential. Many foods have physical characteristics that make conduction the primary mode of heat transfer during thermal processing. These foods are the most difficult to heat since the body mass of the food serves as insulation between the heat source and the center of the food or point of minimum temperature (Dickerson, 1965).

According to Dickerson and Read (1968), the calculation of heat transfer in foods depends on the identification of the thermal properties and geometry of the food and on thermal processing conditions. The thermal properties establish how heat is distributed within a food. The average rate of temperature rise is determined by density and specific heat and by heat flow into the food (Dickerson, 1965).

The thermal conductivity (TC) of the food and the characteristics of the thermodynamic medium at the food surface establish the heat flow at the food boundary. The thermal diffusivity (TD) of the food determines the shape of the internal temperature profiles (Wadsworth and Spadaro, 1969).

Thermal diffusivity (a) is a measure of the quantity of heat absorbed by a material for a given temperature change, and further indicates the ability of the material to conduct heat to adjacent molecules. TD may be expressed in terms of other thermal properties according to the formula:

$$a = \frac{K}{pCp}$$

where a = Thermal diffusivity of unknown fluid

K = Thermal conductivity

p = Density

and Cp = Specific heat at constant pressure

On the right of the equation, the denominator represents heat absorbing capacity whereas the numerator represents heat conducting ability (Dickerson and Read, 1968).

There are two general approaches to the problem of measuring TD. It may be calculated from the above formula or it may be measured directly. In the first approach, TC values, density, and specific heat may be evaluated by either transient or steady-state methods.

The method most often associated with steady-state conditions is that of the guarded hot plate (ASTM, 1955), a modification of the parallel plate method (Woodams and Nowrey, 1968). This method yields only a measurement of TC; furthermore, simultaneous determinations of density and specific heat are required for evaluation of TD. Also, these data are needed for several temperature levels. A separate period of temperature stabilization is required for each TC measurement (Dickerson, 1965). Since TC, density, and specific heat values are not generally available for foods, and each property represents a separate determination at several temperatures, the direct measurement of TD is preferred.

Because TD is an indirect measure of "heating time," the transient method is required for this approach (Wadsworth and Spadaro, 1969). An apparatus such as would be needed for the direct measurement of TD has been described by Dickerson (1965).

A second factor necessary for the calculation of heat transfer is information about the geometry of the food. The geometry establishes relationships among surface area, volume, and configuration (Dickerson and Read, 1968). The common shapes of sphere, cylinder, block, and cone are mathematically tractable, and most foods are only slight variants of these shapes. In thermal processing, the temperature of the heat source and the initial temperature difference between heat source and food surface are factors that influence heat transfer (Dickerson, 1965).

Determination of Thermal Characteristics

Generally, the thermal properties of foods are determined by 4 methods or their modifications (Woodams and Nowrey, 1968). These are the thermal diffusing method, the parallel plate method, the concentric sphere method, and concentric cylinder method. Qashou *et al.* (1970) discussed a fifth method, the line-source technique. All but the thermal diffusing and the line-source methods require a steady-state condition in the sample under investigation. This does not favor characterization of thermal properties in a food system where a non-steady state condition prevails.

Thermal diffusing method. The thermal diffusing method is an indirect method for measuring thermal conductivity (TC). If the thermal diffusivity (TD), density, and specific heat of the unknown fluid are measured, TC then may be calculated.

Gane (1936) used the thermal diffusing method to estimate thermal conductivities of some fruit tissues. He inserted thermocouples at the surface and center of a given fruit which had been stored 24 hrs at 59°F and thereafter at 32°F. At intervals of 1/2 min, temperatures were recorded. By assuming that fruits could be represented by spheres of equal volume, the thermal diffusivities of the fruit were calculated from the thermocouple data with the aid of curves developed by Gurney and Lurie (1923). TC values were computed from measured values of TD and density assuming specific heat values of 0.9 in all cases. Kethley *et al.* (1950) made similar attempts to estimate the TC of various fruits and vegetables in the range of 0-80°F. This method for calculation of TC can be used only for nearly spherical foods.

Parallel plate method. In a general overview of the literature, it appeared that the parallel plate method or its modifications were used most often to evaluate thermal characteristics. As early as 1938, parallel plates were used to determine TC and TD values for ice (Hardy and Soderstrom, 1938). The fluid to be studied is sandwiched between two horizontal flat plates. This configuration reduces convection through the fluid layer to a minimum if the top plate is cooled. The TC is calculated from equilibrium conditions by:

$$Q = \frac{KA\Delta T}{L}$$

where Q = Rate of heat flow through fluid layer
K = TC of fluid layer
A = Cross sectional area of fluid layer
L = Thickness of layer
and ΔT = Temperature difference across layer

Most recent research utilizes a modification of the method described above. Miller and Sunderland (1963) measured the TC of frozen beef with a modified guarded hot-plate apparatus similar in basic design to that recognized by ASTM (1955) as standard equipment for application to insulating materials. A modification of the parallel plate also was used to obtain thermal values for frozen and fresh beef, pork, lamb, and veal in the temperature range 0 to 150°F (Hill *et al.*, 1967).

Smith et al. (1952) determined values for black currants, strawberries, plums, beans, potatoes, and carrots using a modification of the parallel plate method. Using a similar method, Lentz (1961) determined TC and TD values for salmon, codfish, seal blubber, lean pork fat, beef, and turkey breast and leg muscles. Similarly, Walters and May (1963), evaluated TC and TD values for broiler and ham muscle and skin.

Concentric cylinder method. Equipment for this method consists of two cylinders assembled coaxially. The inner cylinder is heated by means of an electrical network and the outer cylinder is cooled by a waterbath. The unknown fluid occupies the annular space between the two cylinders. Thermocouples are used to measure the temperature difference across the fluid. From the geometry of the test cell, the value of the TC of the fluid is calculated from Fourier's law:

$$Q = \frac{2\pi \ KL\Delta T}{L_n(R_o/R_i)}$$

where Q = Rate of heat flow

K = TC of fluid

L = Length of apparatus

ΔT = Temperature difference across the fluid

and R = Radius of annulus

Subscripts o and i denote outer and inner surfaces of annulus (Woodams and Nowrey, 1968).

The concentric cylinder method has been used mainly with liquids. In 1949, Riedel (Woodams and Nowrey, 1968) obtained measurements of TC of sucrose solutions, fruit juices, and milk using the concentric cylinder device. Kern (1950) and Lange (1956) studied several organic acids. Thermodynamic properties of fish and their effect on rate of freezing were investigated by Long (1955).

Concentric sphere method. Similar to the concentric cylinder method is the concentric sphere device used to determine TC. The latter employs two concentrical spherical chambers with the unknown fluid located in the resulting annulus. Fourier's law for spherical surfaces is used to calculate the TC of the fluid:

$$Q = K \sqrt{A_o A_i} \frac{T_o - T_i}{R_o - R_i}$$

where A = Surface area of spherical annulus

and rest of symbols are same as for the concentric cylinder method (Woodams and Nowrey, 1968)

Lentz (1961) cited work conducted by Cherneeva (1956) who used concentric spheres to obtain TD and TC values for beef fat and lean muscle and pork fat and lean muscle. Oxley

(1944) also used this method to study thermal characteristics of maize, oats, and wheat.

Transient line-source technique. The transient line-source technique was used by Qashou *et al*. (1970) to determine TC values. Since this method does not require calibration, gives good accuracy, and causes a minimum of disturbance to the material being measured, it is considered as particularly attractive for use on ground meat and other foodstuffs. The basis of the technique is as follows:

> The temperature rise at any point in an infinite solid containing a suddenly initiated, constant-rate, line heat source is a function of spatial position, time thermal properties of the solid, and source strength (Qashou *et al*., 1970).

The technique involves imbedding a fine heater wire (40 gage nickel chrome) along the major axis of a cylindrical sample and placing a 24 gage iron-constantan thermocouple contiguous to the heater wire. An initial uniform temperature in the sample is established by environmental conditioning. Then, power to the heater is initiated and the thermocouple response is monitored. TC then is calculated from:

$$t_2 - t_1 = \frac{\underline{9'}}{4\ K} \ln \frac{[T_2 - T_o]}{[T_1 - T_o]}$$

where $t_2 - t_1$ = Temperature change between T_1 and T_2

$\underline{q}'$ = Continuous line-source strength

K = TC

and T_o = Correction term that accounted for discrepancies from theory such as finite radius of the heater wire, contact resistance, and difference between source and sample

Using the technique described above, Qashou *et al.* (1970) determined TC values for ground beef and chuck. The experimental variables were temperature, time, and power to the line heat source. Conductivity values were consistent with those in the literature.

Some of the advantages in using the line-source technique are that no special dimensions are required for the test specimen and the transient test is short in duration. Since only a small temperature change is imposed during the test, the sample is not damaged. Perhaps most important is that with this method simultaneous determination of TC and TD can be made.

The theoretical and experimental bases for the use of the line-source technique for TD measurements are discussed by Dickerson (1965). TD is determined under transient heat transfer conditions. A complete determination requires less than 24 hrs and not only provides data from which TD is calculated, but also indicates points of discontinuity that can be associated with the melting of fats or other changes of state within the food system.

Modified heat penetration method. The foregoing discussion was concerned with methods for determining thermal characteristics of various biological materials using some sort of conductivity cell. It must be noted that some authorities advocate determining TC and TD mathematically from heat penetration data obtained experimentally. Charm (1963) presented one method for calculating the TC of frozen foods and the heat-transfer coefficient associated with freezing systems by simply employing the heat-penetration curve. The heat-transfer coefficient and TC values of codfish were determined by this method and were in the range of reported values.

Transient temperature distributions were determined experimentally by Wadsworth and Spadaro (1969) for sweet potatoes heated in a waterbath at selected temperatures. Experimental time-temperature curves were used to calculate TD values. A comparison of heating curves with the experimental time-temperature curves indicated excellent agreement. Therefore, if the application of the mathematical model approach is feasible, experimental determinations for TC and TD values may become obsolete.

Effects of Heating on Moisture

Total moisture. It is generally accepted that the total moisture of meat decreases during cooking. As early as 1938, Satorius and Child (1938) cooked beef *semitendinosus* muscles to end point temperatures of 58, 67, and 75°C and observed that total moisture (TM) decreased as internal temperature increased from 58 and 67°C to 75°C. There was no observed difference in TM between 58 and 67°C. The observed loss was attributed to possible changes in the colloidal structure resulting from coagulation.

Sanderson and Vail (1963) reported that TM decreased with increasing internal temperature (140, 158, and 176°F) in both oven- and tube-cooked *longissimus dorsi* muscle of Good and Choice grades of beef. For pork loin roasts (*longissimus dorsi* muscle) cooked to end point temperatures of 65, 75, and 85°C, Pengilly and Harrison (1966) also observed that TM decreased with each 10°C increment.

Rogers *et al.* (1967) studied the moisture changes in turkey breast and thigh-leg muscles resulting from roasting to end points of 10, 25, 35, 45, 55, and 65°C. Total moisture was determined by air and *in vacuo* drying. As measured *in vacuo,* TM in the *pectoralis major* muscles decreased from 74.33% in the uncooked (10°C) samples to 68.69% in the samples heated to 65°C. The greatest change in TM occurred between the 10 and 25°C samples.

Cooking losses. Cooking losses include volatile as well as drip loss. The latter loss includes fat, muscle, salts, and nonnitrogeneous and nitrogeneous extractives

(Lowe, 1955). Ritchey and Hostetler (1964) reported that water was the main component of cooking loss when beef steaks were heated to internal temperatures ranging from 61 to 80°C; whereas, only 2% of the cooking loss was fat and other solids. These findings supported the statement of Lowe (1955) that volatile losses were primarily the result of water evaporation but included certain volatile aromatics and fat and protein decomposition products.

Total cooking losses usually increase as end point temperature and time are increased. When *longissimus dorsi* and *semimembranosus* muscles were cooked to internal temperatures of 140, 150, and 176°F, Sanderson and Vail (1963) observed an increase in cooking losses for both muscles with each increase in end point temperature. Goertz and Watson (1964a) roasted turkeys to end point temperatures of 85 and 90°C as measured in the breast muscle. With an increase in cooking time (min/lb), there was an increase in cooking losses. To study the effect of cooking temperatures on broiler acceptability, Goertz *et al.* (1964b) cooked chicken halves to an end point of 203°F in a broiling compartment at increasing temperatures of 350, 375, and 400°F. Slight, although nonsignificant, increases in total, volatile, and drip losses were noted with an increase in cooking temperature.

When Rogers *et al.* (1967) increased end points from 25°C to 65°C, total cooking losses of turkey breast muscle increased from 6 to 17%. Cooking losses were different ($P < 0.05$) with each 10° increment except between 35 and 45°C. The greatest increase in weight loss occurred between 55 and 65°C. Hoke et al. (1968) also reported increased ($P < 0.01$) total cooking losses of turkeys cooked to 165, 175, and 185°F.

Water holding capacity. The ability of muscle to retain water was reported by Hamm (1960) as an important characteristic of meat since it was closely related to taste, tenderness, color, and other features of meat quality. Water holding capacity (WHC) was defined as "the ability of meat to hold fast to its own or added water during application of any force (pressing, heating, grinding, etc.)."

In a review of meat hydration, Hamm (1960) observed that muscle proteins were mainly responsible for water-binding in meat. Four to 5% of the moisture was tightly bound by hydrophilic groups in mono- and multimolecular layers between the peptide chains of the protein. This water was not influenced substantially by changes in protein structure and changes on the protein molecule.

Water not tightly bound is considered as loose water. Hamm (1960) termed the mechanism by which loose water is held electrostatically as the net change effect. Peptide chains of protein molecules possess free electrical charges which result from the presence of negative carboxyl and positive amino groups. Polar groups which attract the dipolar water molecules also are present. However, when inter- and intramolecular salt linkages occur, only the net charge of the protein affects WHC and this effect is minor. The spatial relationship of muscle protein affects its hydration. Cross linkages such as those of salts, bivalent metals, disulfides, or hydrogen bonds connect the peptide chains: thus, a number of charged groups becomes unavailable for water-binding because of insufficient space for the water molecules. Upon cleavage of the cross linkages, the peptide chains become more flexible and water is attached to polar groups. Usually the net charge effect accompanies the stereo effect.

WHC usually decreases as temperature increases. However, Satorious and Child (1938) noted a marked delay in hydration changes (WHC) in the temperature range between 50 and 55°C. Hamm (1960) attributed this phenomenon to a delayed decrease in acid groups. In a study of the effect of cooking temperatures on the water holding capacity of ground loin, Wierbicki _et al._ (1957) concluded that reactions occurred between 55 and 65°C that counteracted the trend toward water loss by the proteins. Rogers _et al._ (1967) reported decreased water retention (greater loose water) in turkey _pectoralis major_ muscle as end points increased from 10 to 65°C.

CHAPTER III

PROCEDURE

Turkey pectoral muscles were used to investigate the relationship of thermal properties and water-holding capacity. Ground pectoralis secundus muscles were heated at and to end point temperatures at 18 degree intervals between 77 and 185°F with 0 and 15 min holding times. An appropriate experimental design for the two variables (end point temperature and holding time) was used to collect data for determination of selected thermal characteristics, the expressible moisture index (EMI), total cooking loss, and total moisture (%). Representative raw samples were analyzed for total moisture (%), total fat (%), and EMI.

Preparation of Sample

Thirty Nicholas tom turkeys of known history, including feeding regime and processing procedures, were obtained fresh (nonfrozen) from Wampler Foods, Inc., Hinton, Virginia. The turkeys were U. S. Grade A, approximately 25 wks old and weighed between 24-26 lbs with giblets. After slaughter and eviseration, the birds were chilled to a temperature of 35-37°F in a chilling vat containing crushed ice and water. Air was bubbled throughout the mixture until the desired temperature was reached. The turkeys were placed in plastic bags 12 to 16 hrs after slaughter, packed two birds per wooden crate, and surrounded with crushed ice for transportation to Knoxville, Tennessee (approximately 8 hrs). Upon arrival in Knoxville, the temperature of the birds was maintained at 37 to 45°F by storing in chipped ice for an additional 13 to 19 hrs before dissection.

The turkeys were arbitrarily divided into three lots of 10 each to facilitate handling. The pectoralis secundus (PS) muscles were removed from the turkeys, placed on Saran wrap over crushed ice, and covered. During dissection, lot mixing, and grinding, the temperature ranged from 45-53°F. After dissection, the tendon was removed from the PS, and the muscle was cut into 1/2 to 1 inch chunks, placed in a plastic bag, and surrounded with crushed ice. The chunks were mixed manually to insure randomness within a lot.

Each lot was ground four times through the plates of a Hobart Grinder (Model 4722). The sample was ground through Plate A, then Plate B, and finally, twice through Plate C. The pore sizes were 1.0, 0.5, 0.25cm respectively. Dry ice was ground through the Hobart periodically to maintain the temperature. When the final grind was completed, the sample was weighed into 60g portions, wrapped in precoded aluminum foil (0.0007 gage), and frozen at 0°F in an institutional size freezer. The samples were frozen within 48 hrs and then were placed by lots into large plastic bags and stored at 0°F 4-6 months prior to use.

Determination of Thermal Characteristics

Apparatus. The apparatus and associated equipment shown in Figure 1 are a modification (Holmes, 1972) of the transient line-source technique reported by Qashou *et al.* (1970). A water-jacketed infinite cylinder with necessary associated wiring was used to collect the data for calculation of thermal properties (Figure 2). The pyrex cylinder was 2.8cm diameter with the length being greater than twice the diameter. Each end of the cylinder contained a plastic-fitted disk through which the two thermocouples and the single resistance wire were strung. A closed system was completed by stoppering the cylinder with tight-fitting vertically-split black rubber stoppers.

Thermocouple wires of 30 gage copper and constantan wire were joined and soldered (high resin solder; 60% tin, 40% lead) as a vertical junction. A 24 point Honeywell Electronik 16 recording potentiometer was used on selected junctions to record the temperature of samples at 15 sec intervals. Voltage and amperes of the chromel-C resistance wire (ohms: 6.54 per foot, size 30-010) were determined using a Simpson Model 157 voltmeter (0-25 AC volts) and a General Electric AC Ammeter (0/5/10/20 amperes), respectively. Total voltage along the line was controlled and maintained with a variac.

Figure 1. Modified line-source apparatus.

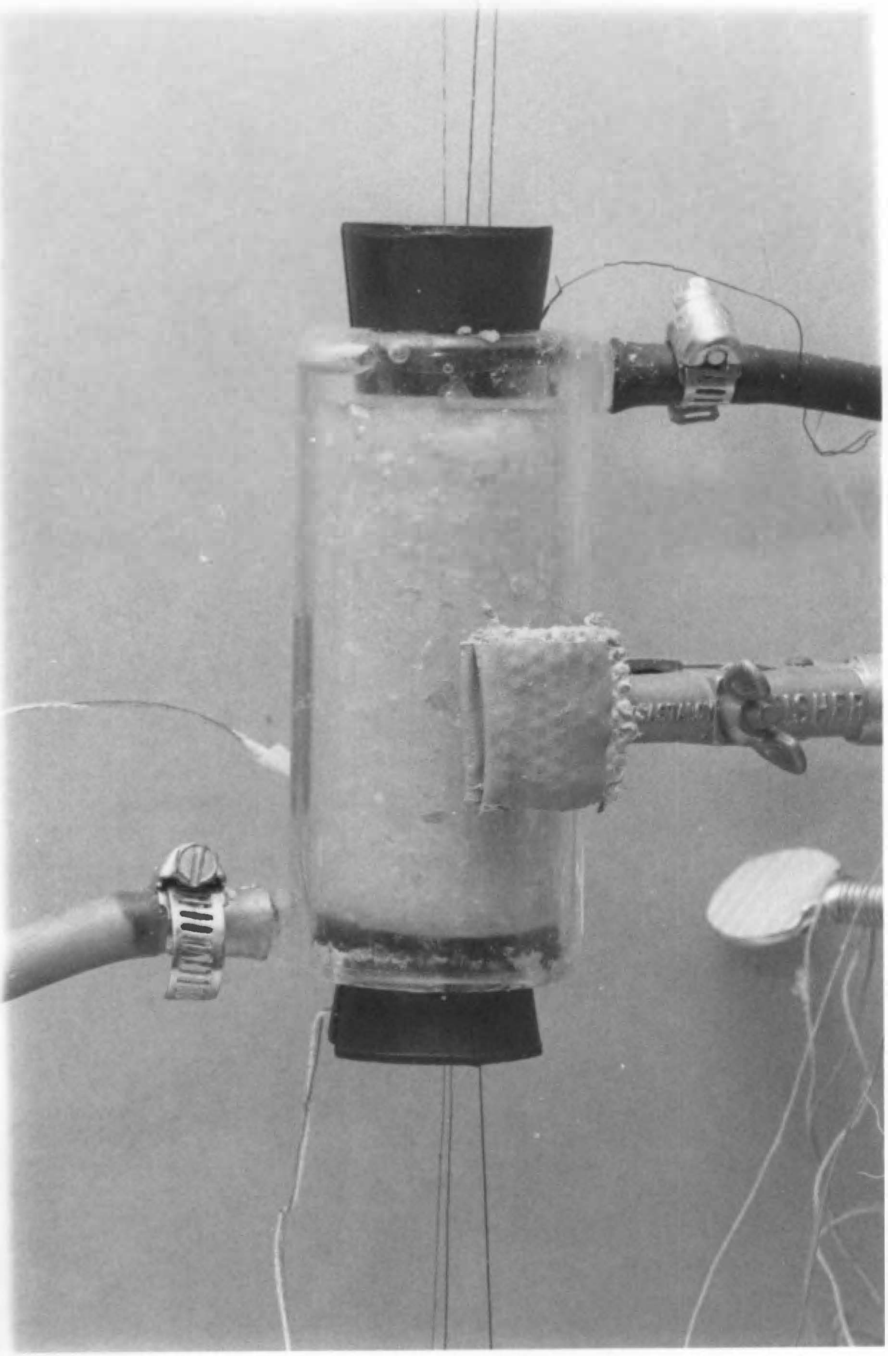

Figure 2. Jacketed cylinder used for heating samples to end points.

Water at the selected temperatures (±2.0°F) was pumped through the cylinder using a Sears Submersible Pump (Model 27711: 0.7 amperes; approximately 140 gals/hr). Waterbath temperatures identical to the selected end point temperatures were maintained in meat samples with a Model 83 Precision Scientific Products Waterbath.

Method. Each packaged turkey sample was defrosted at approximately 77°F for 2-3 hrs. Sampling was conducted according to the plan outlined in Table I. Upon packing approximately 51.5g of the turkey into the cylinder, sample height was recorded. From an initial temperature of approximately 77°F, samples were heated to the selected end point temperature. When the temperature was constant throughout the sample and it was held for the appropriate holding time, approximately 5 volts was applied to the resistance wire. Temperature increase, voltage, and amperes were recorded for approximately 2 mins. At the end of the 2 min data-collection period, voltage was turned off and the cooling vat used to supply circulating water to return the sample to the initial temperature (77°F). Representative turkey samples for each treatment and replication were removed for expressible moisture index and total moisture determinations. Page 49, Appendix, provides detailed information on the Holmes' (1972) method.

TABLE I

SAMPLING PLAN OF TREATMENTS USED FOR GROUND *PECTORALIS SECUNDUS* MUSCLE[1]

Temperature (°F)	Holding Time (min)	
	0	15
77	5	7
	28	19
95	20	11
	17	6
113	4	27
	12	18
131	13	21
	1	24
149	26	15
	16	9
167	25	2
	10	23
185	3	22
	14	8

[1] The number indicates order of preparation within the experiment.

Thermal characteristics. TC heat curve data were used to obtain thermal conductivity and diffusivity values. The term "TC heat curve" designated the temperature difference from the appropriate end point temperature throughout the operation of the data collection time when the heat source was functional. Temperature rise was standardized by using the difference of temperature rise in relation to the initial temperature at 0.0 time.

Temperature data from the TC heat curve were analyzed with an updated version of the Generalized Curve-Fitting and Plotting Program or GECAP (V-I, 9-15-71) designed for the IBM 360/65 computing system (Beadle, 1971). The TC heat curve which consisted of the seven temperature difference values from 0.0 to 1.5 min time were read into the computer. Individual data points for the four observations within a given temperature were plotted, and calculated best-fit temperature data were graphed simultaneously. Figures A-1 through A-7, Appendix, are examples of the curves produced by this program. Besides curve-fit data, the program printed out a table of calculated temperatures and provided the absolute differences between the experimentally observed data and mathematically calculated values. Also obtained through use of this program was a list of coefficients for the N^{th} degree polynomial calculated by the best-fit function.

The IBM 360/65 computer system was programmed to solve for diffusivity and calculated conductivity (Cowling, 1972). The detailed FORTRAN program written to assist in determining these values is on page 58 of the Appendix. Data input consisted of calculated curve-fit temperatures determined previously with the GECAP (V-I, 9-15-71) program, time values of 0 and 90 sec, radius (R) from heat source to inner thermocouple, and heat input (Q). The latter was calculated according to the following formula:

$$Q = \frac{\left(\frac{I^2 \text{ X } 3.413 \text{ X } 252}{30.5}\right)}{3600}$$

Thermal conductivity was expressed in terms of cal/sec/cm °F (Cowling, 1972).

<u>Determination of Moisture Factors</u>

Total moisture was determined in duplicate on 6g samples dried in a 100°C air oven to a constant weight or for about 24 hrs (Ruff, 1970). Upon removal from the oven, the samples were cooled 1 hr and then weighed. Weight loss, expressed as percent of original weight, was reported as total moisture (%).

Expressible moisture index (EMI) was determined according to Procedure for Operation of Food Testing Equipment (Anon., 1972). Three 300 ± 20mg portions of turkey were positioned on three separate Whatman No. 1 filter papers between four plexiglass plates. The Harco hydraulic press (LB6721) was used to apply 5000 lbs pressure over a 5 min schedule. Areas of the pressed meat and expressed juice were determined with a compensating polar planimeter. EMI was calculated by dividing the meat area by juice area.

In addition to the determinations above, three uncooked, untreated base samples were all analyzed for fat using the method outlined by Ostrander and Dugan (1961) and modified by Turkki (1965). The procedure involved chloroform-methanol extraction, separation, then evaporation of the chloroform. Fat (%) was determined using the following equation:

$$\%\text{Lipid} \begin{pmatrix}\text{Wet wt} \\ \text{basis}\end{pmatrix} = \frac{10(\text{ml total chloroform extract x g fat in 10ml})}{\text{g muscle extracted}}$$

Statistical Methods

A completely random block was used for structuring the design (Steel and Torrie, 1960). The block consisted of randomly-collected data from two replications with all treatment combinations of the two variables: end point temperature and holding time.

The data were assessed by several arrangements of the analysis of variance method. Orthogonal contrasts were used to fit data to regression lines and tested for polynomial fit up through the pentic. Curve-fit data thus obtained were plotted mechanically by a computer (Sanders, 1972). Single-way analyses of variance were used to treat cooking loss data and to treat the data obtained from the analysis of the uncooked, untreated sample.

CHAPTER IV

RESULTS AND DISCUSSION

Treatment Effects on Thermal Characteristics

Thermal conductivity and diffusivity values are presented in Table II. Only thermal conductivity values will be discussed and these will be treated as relative data within the scope of this study.

A decrease in thermal conductivity was observed at the 185°F end point. Values at temperatures lower than 185°F tended to be similar. Few if any thermal conductivity values for turkey or other meat have been determined at the specific end points used in this study. However, one study using temperatures ranging from -13 to 36°F indicated that the thermal conductivity of turkey breast muscle decreased gradually as temperature increased to 23°F. Then a marked decrease in thermal conductivity was observed around 32°F (Lentz, 1961). A similar study by Miller and Sunderland (1963) supported this trend. Thermal conductivity was determined on beef from 0 to 40°F at various increments. A gradual decrease was evident as temperatures increased to 30°F. Between 30 and 32°F a more pronounced decrease in thermal conductivity occurred. Thereafter increasing the temperature to 35 and 40°F had little or no effect on thermal conductivity.

TABLE II

THERMAL CHARACTERISTICS OF GROUND *PECTORALIS SECUNDUS* TURKEY MUSCLE

		Thermal Conductivity (cal/cm/sec °F X 10^{-3})		Thermal Diffusivity (cm/sec X 10^{-1})	
End Point (°F)		Holding Time (min)			
		0	15	0	15
77		0.3542	0.4312	0.5551	0.8647
		0.5275	0.2609	0.9339	0.3028
	Avg	0.4408	0.3460	0.7445	0.5838
95		0.3814	0.4655	0.8607	0.9760
		0.4677	0.4722	1.0130	0.9414
	Avg	0.4246	0.4688	0.9368	0.9587
113		0.2306	0.4250	0.4357	0.9192
		0.4167	0.3542	0.7499	0.5551
	Avg	0.3236	0.3896	0.5928	0.7372
131		0.2680	0.3542	0.5596	0.5551
		0.9016	0.4178	2.5880	0.7443
	Avg	0.5848	0.3860	1.5738	0.6497
149		0.4549	0.4909	0.8133	0.8311
		0.4132	0.5219	0.7344	0.7903
	Avg	0.4340	0.5064	0.7738	0.8107
167		0.9137	0.2024	2.0640	0.1257
		0.8263	0.6198	2.1830	1.2170
	Avg	0.8700	0.4111	2.1235	0.6714
185		0.2254	0.2833	0.1295	0.2583
		0.3673	0.2024	0.6595	0.1257
	Avg	0.2964	0.2428	0.3945	0.1920

Therefore, thermal conductivity may not be affected beyond 30°F. Research is needed using temperatures in the ranges above freezing to determine this.

Thermal conductivity values presented in Table II ranged from 0.2254 - 0.9137 cal/cm/sec °F for samples at 0 min holding time. A somewhat smaller range was observed for the samples held 15 min (0.2024 - 0.6198). The latter was probably more accurate in that the temperature rise attributable to the heating medium was known to have become constant before the 5 volts was applied. Therefore, the application of the 5 volts was responsible for any increase in temperature measured. Generally, the agreement between replicates for a given temperature was similar to the range of values reported in the literature using a modified line-source technique (Qashou *et al.,* 1970).

Some discussion of possible reasons for the inconsistency observed within the data is needed. When thermal conductivity values are determined from heat curve data, an error of 0.1°F can lead to a 10% miscalculation of the relative thermal conductivity value (Cowling, 1972). Equipment used for this study was accurate only within 2-3°F. Furthermore, the temperature was recorded within spaces of 2°F increments and had to be read to the nearest 0.1°F for calculation purposes. Also, it was difficult to pack the sample into the cylinder and be certain that air spaces were not in the location of the thermocouple. This error was minimized by packing the container to approximately the same density each time. Finally, there was a difference in fat content among the lots. Some workers have reported lowered thermal conductivity values with increased fat (Qashou *et al.*, 1970).

Using the *pectoralis major* muscle, Holmes (1972) determined thermal conductivity and diffusivity values using the same apparatus as in the present study. She observed similar inconsistencies within her data. Values for thermal conductivity were higher than the ones reported here; diffusivity values were lower. Differences in muscle and in laboratory technique probably were only partially responsible for the observed differences. Upon defrosting, some of the *secundus* samples had possibly undergone some denaturation in that the color was lighter and the texture "mealier." The number of samples with these characteristics increased as storage time increased. Holmes observed no such change with the *major* muscle. The myoglobin and other proteins may have been more sensitive to change in the *secundus* muscle. Freezer burn attributable to the grinding of dry ice with the sample during initial preparation was a possible explanation.

Treatment Effects on Moisture Factors

Tests for homogeneity of regression analyzed effect of holding time on total moisture, cooking loss, and expressible moisture. No significant difference was indicated.

<u>Total moisture.</u> Orthogonal contrasts were used for transfer of total moisture (TM) data to a polynomial. The graph of the polynomial from this analysis strongly suggested an asymptotic function. With respect to this, the data were reevaluated. The following regression equation provided the graph in Figure 3:

$$\hat{\text{TM}}(\%) = 74.49 - 0.0123^{e\ 0.0694\ (\text{Temperature})}$$

Total moisture (TM) values were significantly different ($P < 0.001$) for the end point temperatures (Table A-I, Appendix). TM decreased only slightly as the end point increased from 77 to 113°F (Figure 3). For the 77°F sample, the TM was 74.4%, 74.2% for the 95, and 74.3% for the 113°F samples. Total moisture of these samples was similar to that for the raw untreated sample (74.4%, Table A-II, Appendix). Similarly, Rogers <u>et al.</u> (1967) reported no difference in TM of breast muscles heated to 25, 35, and 45°C (77, 95, 113°F). However, a significant difference ($P < 0.05$) for TM was reported for the 55 and 65° samples. Since a different method of heating was used by Rogers and co-workers than that reported here, this might account for this dissimilarity.

According to data in Figure 3, TM decreased when end point increased to 131°F. There was no difference between the TM of samples heated to 131 and 149°F. Yet both samples exhibited about a 0.5% moisture loss compared to the 113°F

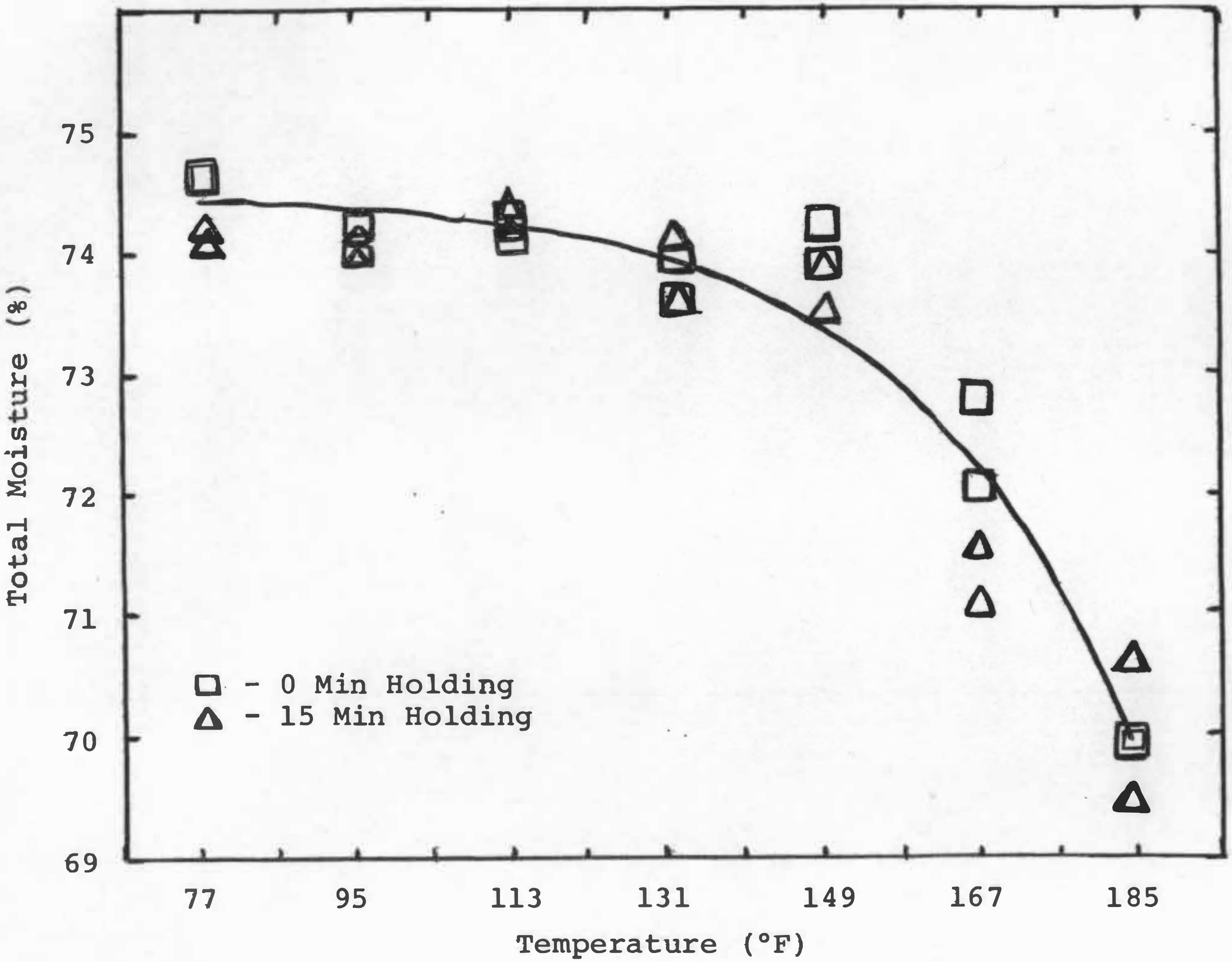

Figure 3. Effects of time-temperature variations on total moisture of ground *pectoralis secundus* turkey muscle.

sample. As early as 1938, Satorius and Child (1938) noted similar values for TM for beef semitendinosus samples cooked to end points of 58 and 67°C (136, 153°F).

As end points increased from 149 to 185°F, there was a pronounced decrease in the amount of water retained. TM of the 167°F sample was 2.1% lower than that for the 149°F, and there was a 1.7% decrease in TM from 167 to 185°F. Sanderson and Vail (1963) observed a trend similar to this in their work on three different beef muscles. As end point increased from 140 to 158 to 176°F, marked decreases in TM for all three muscles were evident.

Holmes (1972) in a similar study reported no difference in TM for pectoralis major samples heated to end points of 77, 95, 113, 131, and 149°F; however, there were obvious decreases in TM when samples were heated beyond 149 to 167 and 185°F.

TM data in the present study were compared to literature values only with respect to trends. When work was conducted on turkey or poultry muscles as affected by end point, the experimental conditions were different. In the present study, the sample was in a closed system heated by water at the desired end point. In most of the other studies, samples were heated in an open or semiclosed system.

Cooking loss. These values were calculated from the difference between weights before and after cooking (Table III). As end points increased from 77 to 95 and 113°F, there

TABLE III

COOKING LOSS[1] OF GROUND *PECTORALIS SECUNDUS* TURKEY MUSCLE AS AFFECTED BY SELECTED END POINT[2,3]

End Point (°F)	Cooking Loss 0 (g)
77	0.5^{a}
95	1.4^{b}
113	1.5^{b}
131	2.4^{c}
149	3.6^{c}
167	7.3^{d}
185	9.5^{e}

[1] Average of loss values for 2 replications of 2 holding times.

[2] Values with a common superscript are not significantly different.

[3] 77 to 95 and 113°F ($P < 0.001$), to 131 to 149°F ($P < 0.01$), to 167°F ($P < 0.05$), to 185°F ($P < 0.05$).

was a significant ($P < 0.001$) increase in cooking losses; however, they were similar for samples heated at 95 to 113°F and for the 131 to 149°F end point. Cooking loss differed significantly ($P < 0.01$) between the 95, 113, and the 131, 149°F end points. Thereafter, as end point increased from 149 to 167 to 185°F, there was a corresponding increase in cooking loss ($P < 0.05$). Holding time had no effect on cooking losses at a given end point.

In a similar study, Holmes (1972) observed no difference in cooking loss between the 95 and 113°F and between the 131 and 149°F end points. Her data supported the trend described in the present study (Table III) although actual cooking losses were greater in the Holmes study. Difference in laboratory technique rather than differences between the two pectoral muscles probably was responsible.

The observed trend in cooking loss (Table III) was further supported by the TM data in Figure 3, page 34. As with cooking loss, no difference in TM was observed between 95 and 113 and the 131 and 149°F end points; whereas, with an increase from 149 to 185°F, there was a corresponding decrease in TM. From these comparisons, there appeared to be an inverse relation between TM of the sample and the cooking loss.

Significant ($P < 0.05$) increases in cooking loss of turkey breast muscle with end points from 25° to 65°C (77, 95, 113, 131, 149°F) were reported by Rogers *et al.* (1967). No difference in cooking loss was observed between 35 and 45°C (95, 113°F). Hoke *et al.* (1968) reported differences (P 0.01) in total cooking losses of turkeys cooked to 165, 175, and 185°F.

Expressible moisture index. The polynomial presented in Figure 4 was calculated from the equation:

$$EMI = 6.27-7.12x + 0.036x^2 - 0.000836x^3 + 0.00000885x^4 - 0.0000000347x^5$$

From 77 to 95°F, EMI values were similar to each other and to that of the raw untreated sample (Table A-II, Appendix). A slight decrease at 113°F and a sharp decline at 131°F were observed. A less pronounced decrease in EMI occurred at 149°F and then EMI leveled off. The Holmes study (1972) reported a similar trend when the *pectoralis major* muscle was used.

Hostetler and Landmann (1968) reported changes in fiber width associated with heating that were closely related to changes in water holding capacity (EMI). The muscle fibers were heated from room temperature to 80°C (176°F) on the stage of a microscope.

Heat denaturation of the protein probably accounted for some of the trends observed in Figures 3 (page 34) and 4 and Table III (page 36). Hamm (1966) observed no changes in the colloidal-chemical properties or in the solubility

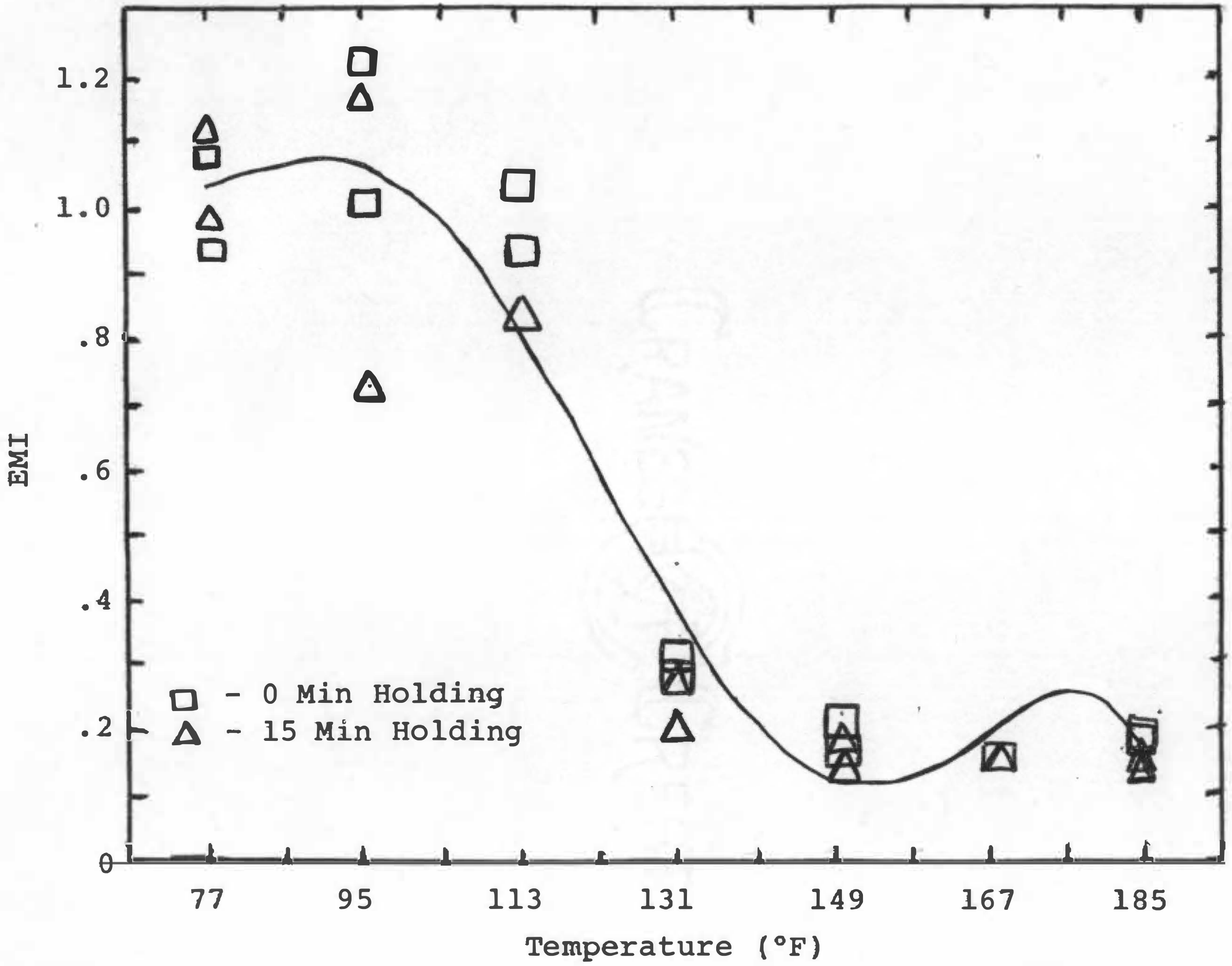

Figure 4. Effects of time-temperature variations on expressible moisture index of ground pectoralis secundus turkey muscle.

of ion-bonding of muscle protein when beef was heated from 20 to 30°C (68, 86°F). Mild denaturation occurred from 30-40°C (104°F). In the data presented here TM and EMI values for 77 - 95°F samples were similar and thus tended to indicate little change in protein denaturation; however, cooking losses increased significantly between 77 and 95°F. The latter is possibly attributed to the effect of time per se rather than to an increase in temperature.

The decrease in TM, increase in cooking loss, and sharp decrease in water holding capacity (EMI) at 131°F probably resulted from strong denaturation of myofibrillar proteins. This is confirmed by Hamm (1966) who indicated that at 149°F most fibrillar and globular muscle proteins were coagulated. In the present study, EMI values displayed little decrease after the 149°F end point. Wierbicki *et al.* (1957) reported that between 140 and 158°F, loss of water holding capacity neared completion, and peptide chains unfolded and meshed together. Obvious decreases in TM and increases in cooking loss beyond 149°F in the present study were probably attributable to the higher temperatures of heating.

CHAPTER V

SUMMARY

Thermal conductivity and diffusivity of ground turkey *pectoralis secundus* muscle were investigated using a line-source apparatus modified to allow determinations upon the sample during transient heating. Samples (51.5g) were heated in a water jacketed cylinder at and to end points of 77, 95, 113, 131, 149, 167, and 185°F and subjected to holding times of 0 or 15 min. The relationship between thermal properties and moisture factors including total moisture, cooking loss, and expressible moisture index (EMI) was investigated.

Thermal conductivity values were similar for samples heated at and to temperatures between 77 and 167°F but tended to decrease for those at 185°F. Holding times did not affect thermal conductivity values. There tended to be close agreement among values for a given end point and these were within ranges reported in the literature.

Total moisture gradually decreased for turkey heated to temperatures that ranged from 77 to 149°F. Thereafter a pronounced decrease in total moisture occurred as end points increased. A significant increase in cooking loss was noted between samples heated to 77 and 95°F ($P < 0.001$), to 113 and 131°F or 149°F ($P < 0.01$), and to 149 < 167 < 185°F ($P < 0.05$).

Expressible moisture indexes for 77 and 95°F samples were similar and decreased slightly at 113°F. A pronounced decrease occurred for samples at 131°F. With further increase in temperature, little difference was observed. EMI were similar for the 149, 167, and 185°F end points. Holding time had little if any effect on all parameters measured.

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APPENDIX

PROCEDURE FOR COLLECTING THERMAL CHARACTERISTICS DATA[1]

1. Defrost sample at approximately 25°C for 2-3 hrs.

2. Record initial package weight. Pack sample into cylinder; record sample height. Weigh package after removing sample. Initial weight minus final weight yields sample weight. Calculation of sample weight per unit length provides an indication of uniform packing from sample to sample.

3. Thermocouples from the sample to a temperature recorder are used to measure temperature at the center and outer edge of the sample. Four recordings are obtained per minute, two for each thermocouple. After the sample has been packed into the cylinder, its temperature is recorded. If the temperature is not 25°C, pump water of approximately this temperature through the cylinder until this temperature is maintained within the sample.

4. Place pump in the waterbath containing the water heated to the approximate end point temperature desired. Turn on temperature recorder. The inner thermocouple temperature should be the first temperature recorded. Simultaneously switch on pump as this temperature is recording.

---

[1] (Holmes, 1972)

5. Allow sample to heat until a constant temperature (or inner and outer thermocouples record the same temperature in succession) is reached. Hold for appropriate holding time.

6. Thermal conductivity and diffusivity data are recorded on the inner thermocouple. When appropriate holding time is complete, there are 15 seconds to move chart paper on recorder forward, push in buttons on recorder so that outer thermocouple will not be recorded, and simultaneously turn on variac as inner thermocouple records. Record nine temperatures (a period of two minutes).

7. Simultaneously turn off variac and pump as last temperature is recorded. Pull out buttons so that outer thermocouple will record. Chart paper is moved forward and the pump is transferred to the cooling vat. As the outer thermocouple begins to record, turn on pump and begin collection of cooling curve data.

8. Cool sample to approximately 25°C. Remove from cylinder to a preweighed container and then record weight after cooking. Initial sample weight minus the final sample weight equals cooking loss.

9. Do Expressible Moisture Index determinations and place Total Moisture (%) sample in air oven.

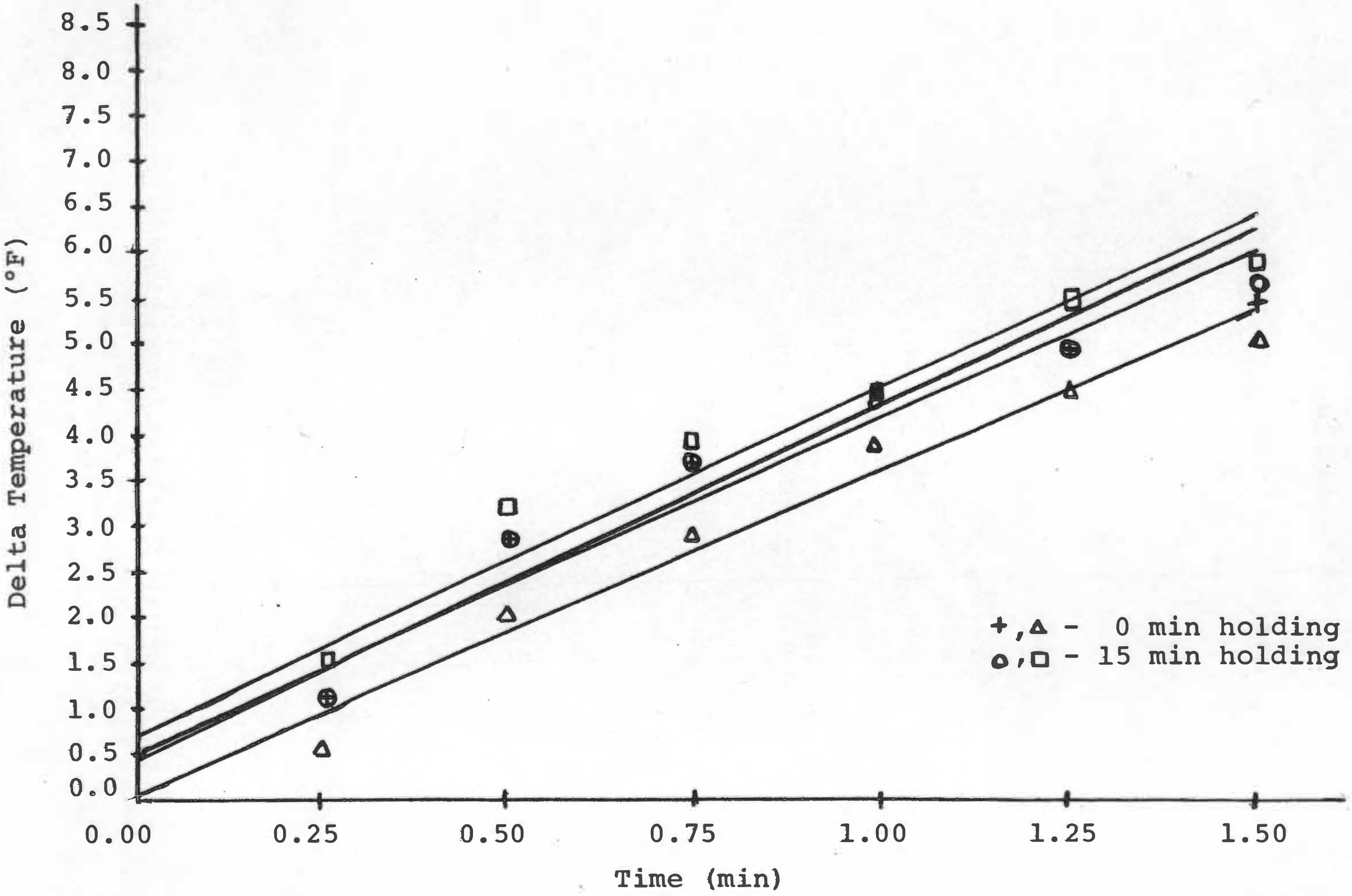

Figure A-1. TC heat curve data (curve-fitted) for ground *pectoralis secundus* turkey muscle heated to an end point of 77°F.

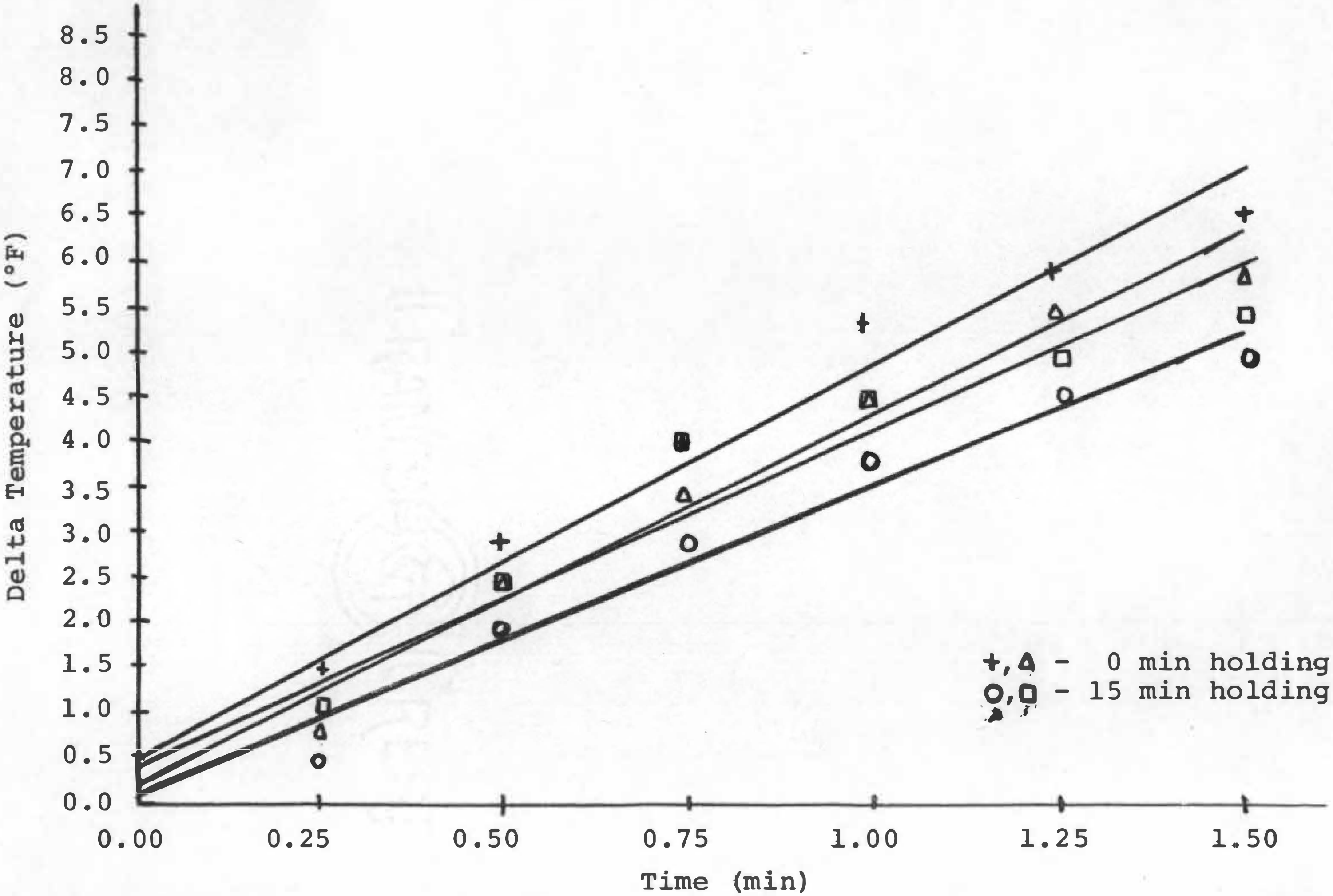

Figure A-2. TC heat curve data (curve-fitted) for ground *pectoralis secundus* turkey muscle heated to an end point of 95°F.

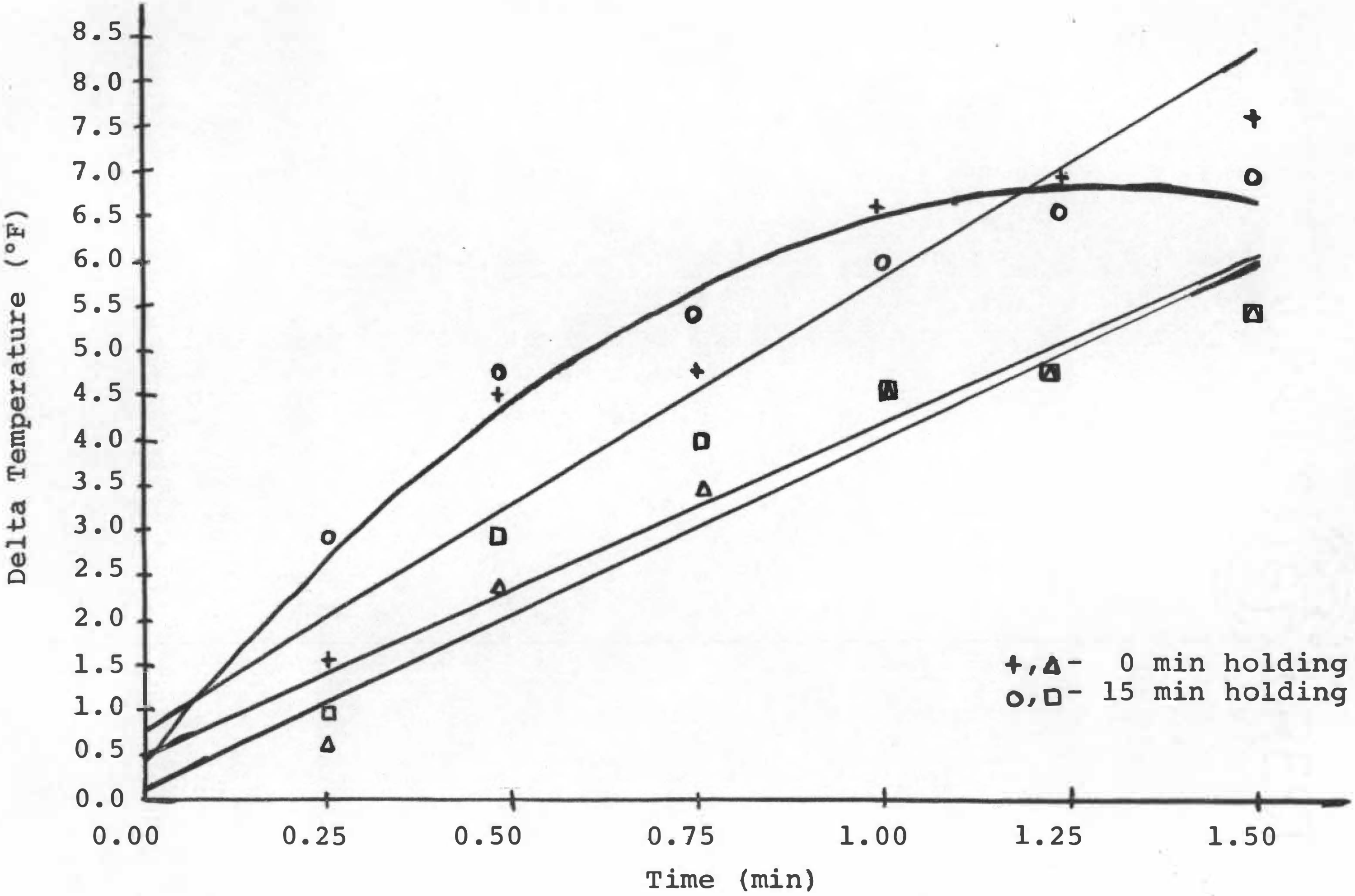

Figure A-3. TC heat curve data (curve-fitted) for ground pectoralis secundus turkey muscle heated to an end point of 113°F.

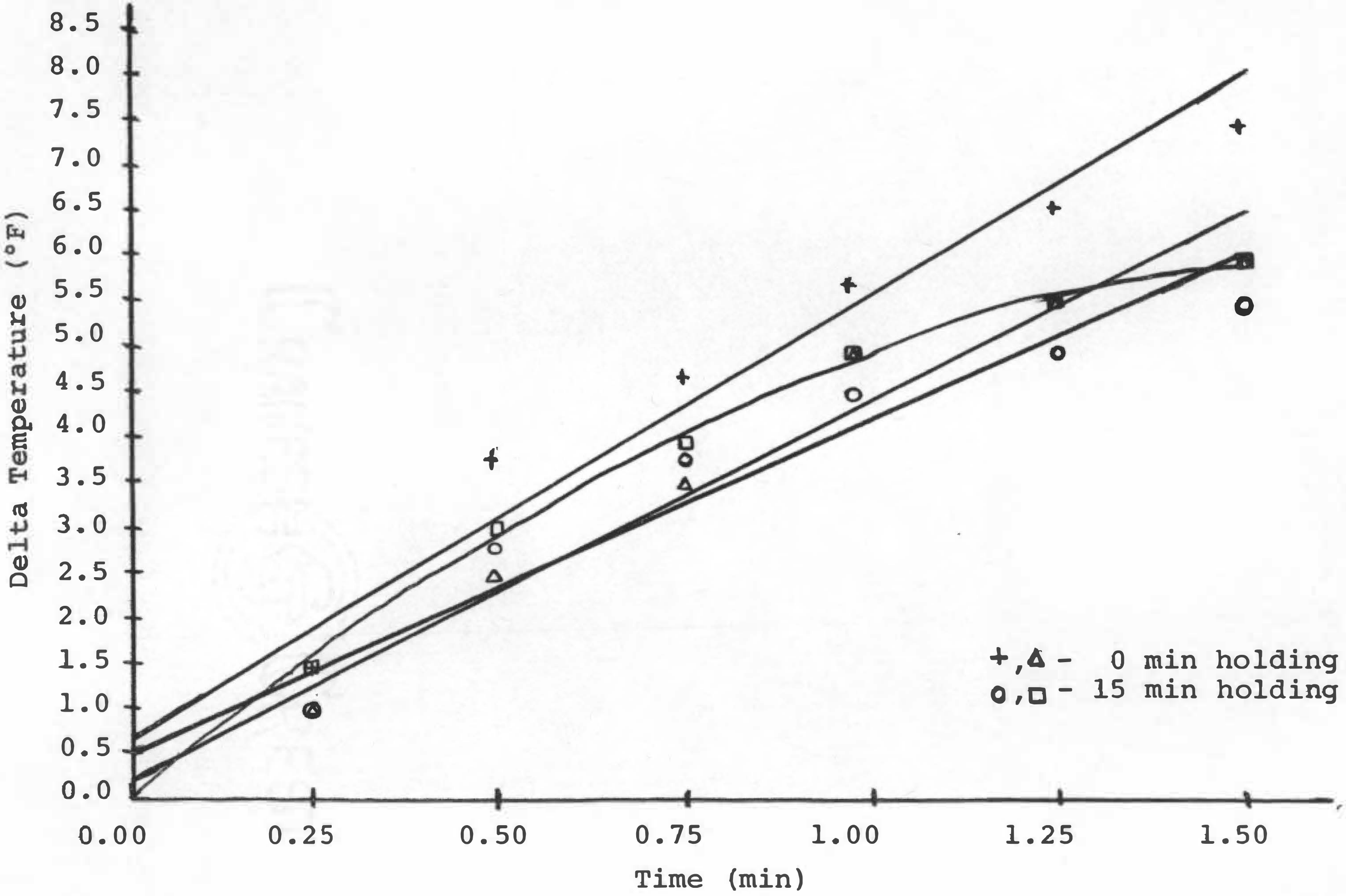

Figure A-4. TC heat curve data (curve-fitted) for ground <u>pectoralis secundus</u> turkey muscle heated to an end point of 131°F.

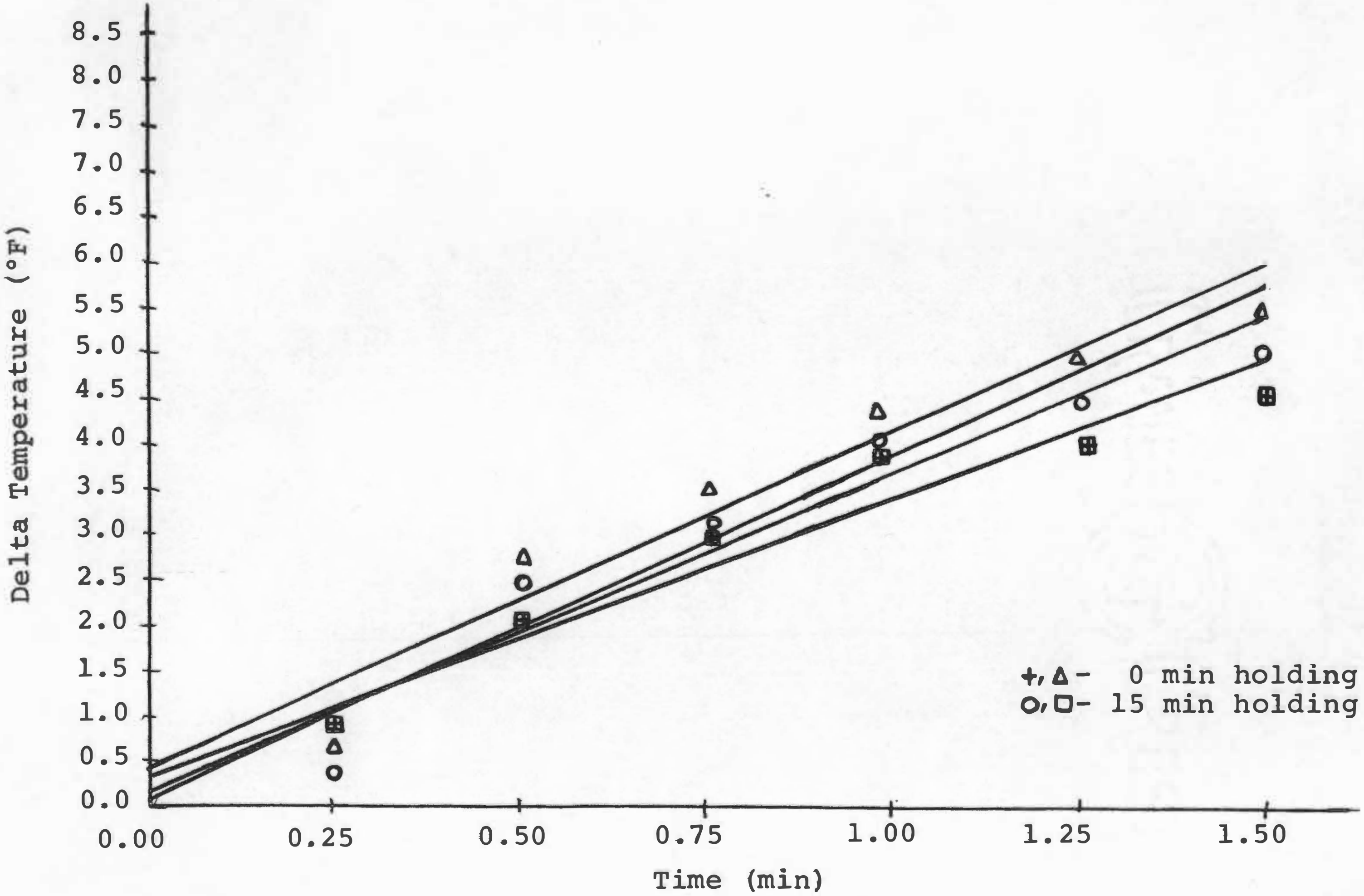

Figure A-5. TC heat curve data (curve-fitted) for ground *pectoralis secundus* turkey muscle heated to an end point of 149°F.

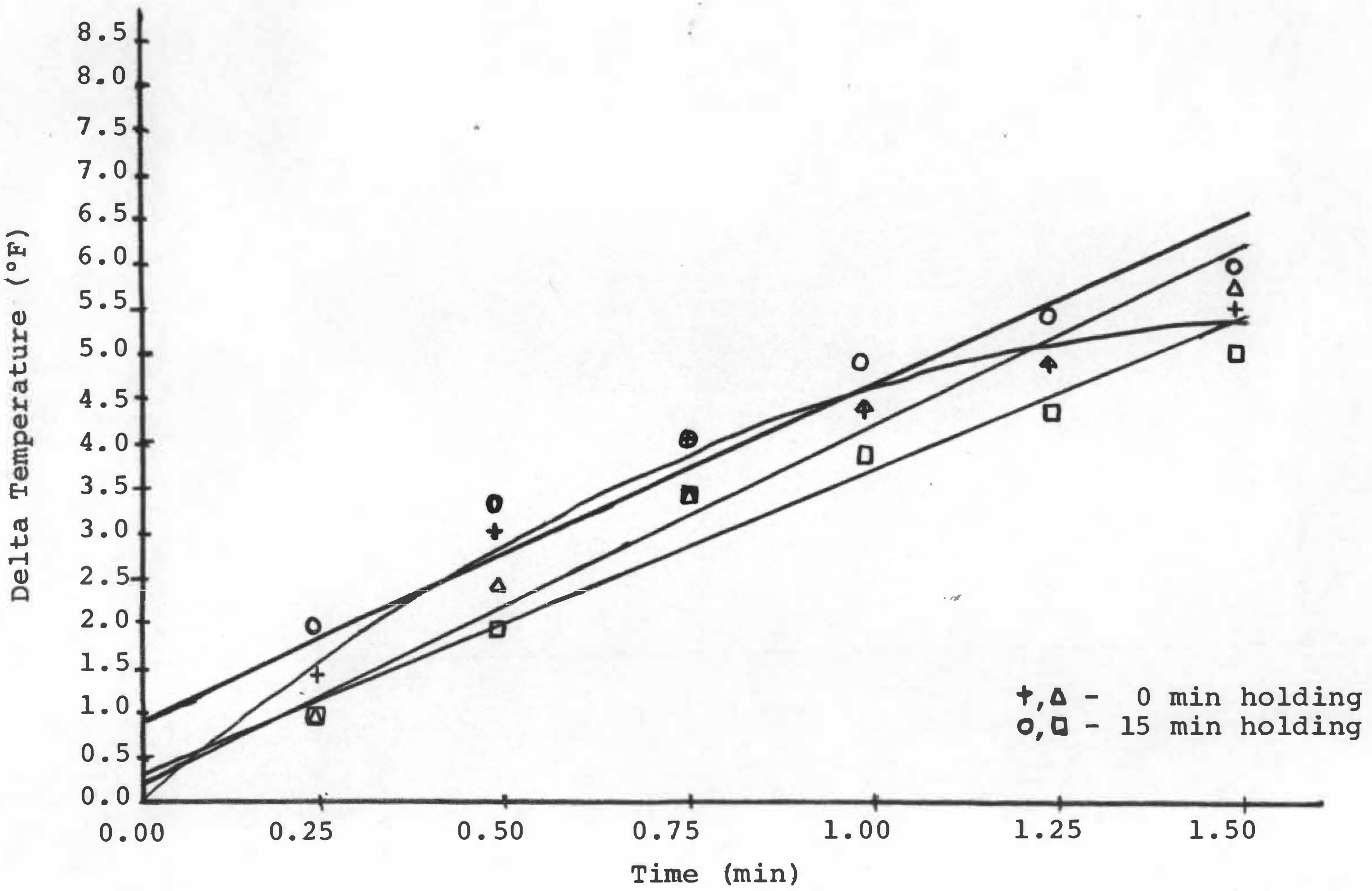

Figure A-6. TC heat curve data (curve-fitted) for ground *pectoralis secundus* turkey muscle heated to an end point of 167°F.

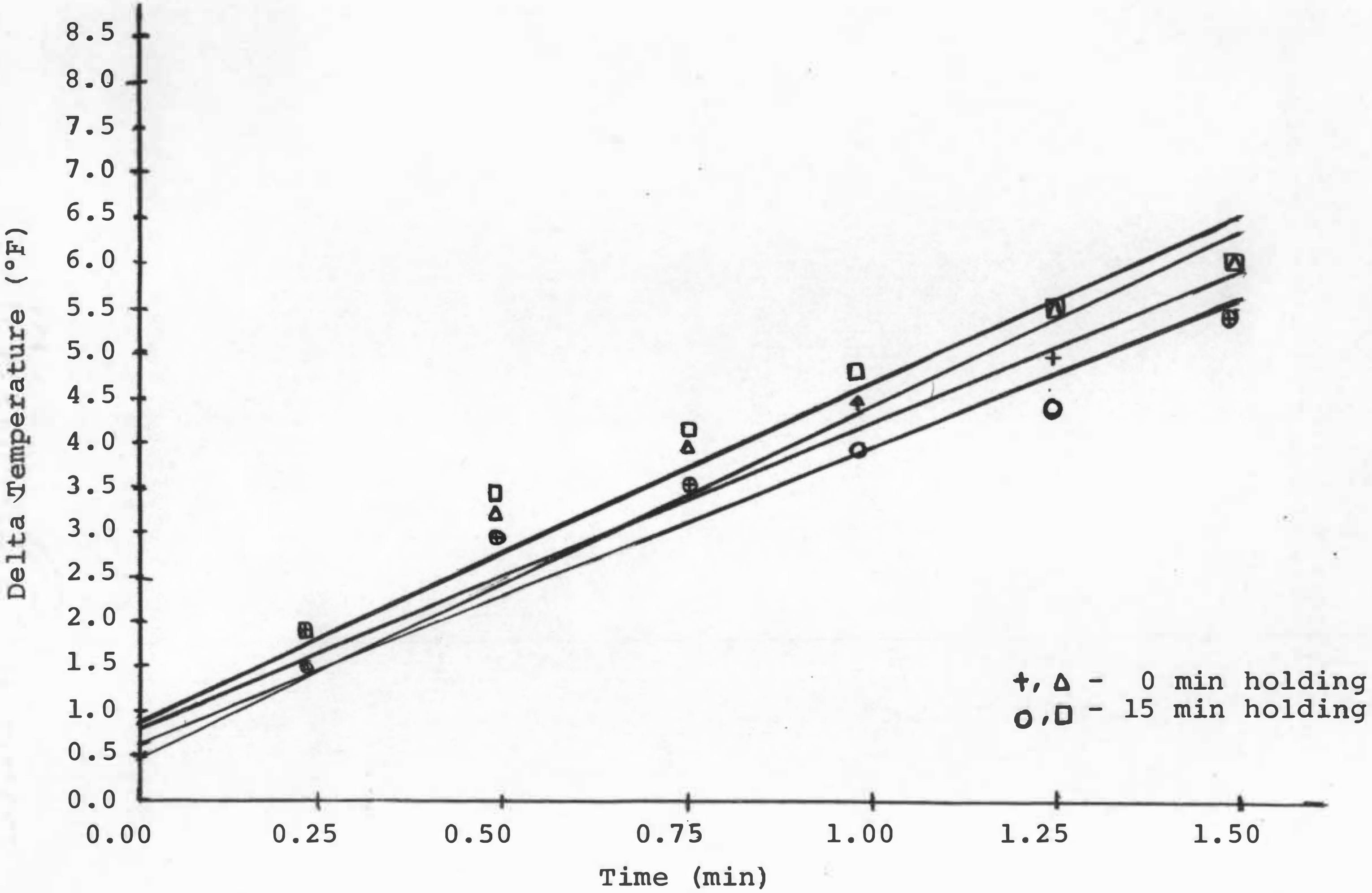

Figure A-7. TC heat curve data (curve-fitted) for ground <u>pectoralis secundus</u> turkey muscle heated to an end point of 185°F.

FORTRAN PROGRAM USED FOR CALCULATION OF THERMAL DIFFUSIVITY AND THERMAL CONDUCTIVITY VALUES[2]

```
      DIMENSION A(40)
900   F(Y)=.32*Y*(T1/V1-T2/V2)+(R**2/12.5-.75-ALOG(R/2.5))
     1*(1./V1-1./V2)-(.8417*BX1*(EXP(-2.35*Y*T1)/V1-EXP
     1*(-2.35*Y*T2)/V2))
901   FP(Y)=.32*(T1/V1-T2/V2)-(.8417*BX1*(EXP(-2.35*Y*T1)/V1
     1*(-2.35*T1)-(EXP(-2.35*Y*T2)/V2*DE)))
      READ 12,N
 12   FORMAT (I10)
      DO 300 J=1,N
      READ 11,R,Q,V1,T1,V2,T2
 11   FORMAT(6F10.4)
      DE=-2.35*T2
      DX=-7.873*T2
      DY=-16.56*T2
      X1=1.5326*R
      X2=2.806*R
      X3=4.0695*R
      PROD=1.
      BX1=1.
      BX2=1.
      BX3=1.
      DO 20 I=1,20
      A(I)=2*I
      PROD=PROD*A(I)
      PBX1=(-1)**I*(X1**A(I))/(PROD**2)
      PBX2=(-1)**I*(X2**A(I))/(PROD**2)
      PBX3=(-1)**I*(X3**A(I))/(PROD**2)
      BX1=BX1+PBX1
      BX2=BX2+PBX2
      BX3=BX3+PBX3
 20   CONTINUE
      PRINT 70
 70   FORMAT(1H ,27X,4H BX1,17X,4H BX2,13X,4H BX3)
      PRINT 80,BX1,BX2,BX3
 80   FORMAT(1H0,20X,3(5X,E15.7))
902   Y=0.4
      Z=F(Y)
      PRINT 140,Y,Z
```

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[2] (Cowling, 1972)

```
140   FORMAT(1H0,20X,3H  I,17X,4H  Y1,17X,7H  F(Y1)/20X,4H
     0,2(8X,F15.16))
      DO 110 I=1,50
      Y1=Y-F(Y)/FP(Y)
      Z=F(Y1)
      PRINT 120,I,Y1,2
120   FORMAT(20X,I4,2(8X,E15.6))
      Y=Y1
      IF (ABS(Z).LT.1.E-5) GO TO 30
110   CONTINUE
 30   S1=Q/(6.2832*V1)*(.32*Y*T1+(R**2/12.51-.75-ALOG(R/2.5)
     1-(.8417*BX1*EXP(-2.35*Y*T1))-(.4524*BX2*EXP(-7.873
     1*Y*T1))-(.3106*BX3*EXP(-16.56*Y*T1)))
      S2=Q/(6.2832*V2)*(.32*Y*T2+(R**2/12.5)-.75-ALOG(R/2.5)
     1-(.8417*BX1*EXP(-2.35*Y*T2))-(.4524*BX2*EXP(-7.873
     1*Y*T2))-(.3106*BX3*EXP(-16.56*Y*T2)))
      PRINT 40,S1,S2,Y
 40   FORMAT(////20X,3E15.6)
300   CONTINUE
      CALL EXIT
      END
```

TABLE A-I

ANALYSIS OF VARIANCE FOR TOTAL MOISTURE (%) AS AFFECTED BY END POINT TEMPERATURES[1,2]

Source of Variation	DF	SS	MS	F
Total	27	67.2418	-------	-------
Explained by model	3	63.2064	21.0688	123.30***[3]
Residual	24	4.0354	0.1681	-------

[1] DF = degrees of freedom; SS, sum of squares; MS, mean square.

[2] TM data fitted to function to give the typical asymptote curve.

[3] *** ($P < 0.001$)

TABLE A-II

TOTAL MOISTURE, TOTAL FAT, AND EXPRESSIBLE MOISTURE INDEX VALUES FOR RAW, UNTREATED SAMPLE[1]

Lot	Total Moisture (%)	Fat (%)	Expressible Moisture Index
A	74.62	1.86	0.9597
B	74.46	2.22	1.5165
C	74.22	1.92	1.3306
Avg	74.43	2.00	1.2689

[1] Individual values represent averages of duplicate determinations.

TABLE A-III

TOTAL MOISTURE (%) FOR GROUND *PECTORALIS SECUNDUS* TURKEY MUSCLE[1]

End Point (°F)		Holding Time (min)	
		0	15
77		74.58	74.22
		74.60	74.33
	Avg	74.59	74.28
95		74.06	74.22
		74.28	74.12
	Avg	74.17	74.17
113		74.14	74.26
		74.28	74.36
	Avg	74.21	74.31
131		73.69	73.72
		73.96	74.08
	Avg	73.82	73.40
149		74.06	73.54
		73.90	73.88
	Avg	73.98	73.71
167		72.58	71.07
		72.02	71.58
	Avg	72.30	71.32
185		69.98	69.64
		69.96	70.66
	Avg	69.97	70.15

[1] Individual total moisture values for each of the 2 replications within a given temperature represent averages of duplicate determinations.

TABLE A-IV

COOKING LOSS (g) FOR GROUND *PECTORALIS SECUNDUS* TURKEY MUSCLE

End Point (°F)		Holding Time (min)	
		0	15
77		0.5	0.5
		0.5	0.5
	Avg	0.5	0.5
95		1.5	1.5
		1.0	1.5
	Avg	1.2	1.5
113		1.0	1.5
		2.0	1.5
	Avg	1.5	1.5
131		2.5	2.5
		2.5	2.0
	Avg	2.5	2.2
149		2.5	5.0
		5.0	2.0
	Avg	3.8	3.5
167		6.0	8.0
		5.5	7.5
	Avg	5.8	7.8
185		10.0	7.0
		10.0	11.5
	Avg	10.0	9.2

TABLE A-V

F RATIOS FOR COOKING LOSS OF GROUND *PECTORALIS SECUNDUS* TURKEY MUSCLE AS AFFECTED BY END POINT[1]

End Point Comparisons (°F)	F Ratio	Significance[2]
77 vs 95	49.0801	***
95 vs 113	0.2733	NS
113 vs 131	13.3737	**
131 vs 149	2.3809	NS
149 vs 167	9.8171	*
167 vs 185	6.6404	*

---

[1] Preliminary of data for 0 and 15 min holding times revealed no significant difference between these factors.

[2] *$P < 0.05$
**$P < 0.01$
***$P < 0.001$
NS nonsignificant

TABLE A-VI

EXPRESSIBLE MOISTURE INDEX VALUES FOR GROUND *PECTORALIS SECUNDUS* TURKEY MUSCLE[1]

End Point (°F)		Holding Time (min)	
		0	15
77		1.0748	1.1249
		0.9224	0.9694
	Avg	0.9986	1.0472
95		0.9758	1.1638
		1.2139	0.7183
	Avg	1.0948	0.9410
113		0.9763	0.8292
		0.8878	0.8288
	Avg	0.9320	0.8290
131		0.3031	0.2839
		0.2845	0.2419
	Avg	0.2938	0.2629
149		0.1835	0.1715
		0.2135	0.1960
	Avg	0.1985	0.1838
167		0.1542	0.1480
		0.1487	0.1594
	Avg	0.1514	0.1537
185		0.1837	0.1720
		0.1867	0.1611
	Avg	0.1852	0.1666

[1] Expressible moisture index values for each of the 2 replications represent averages of duplicate determinations.

VITA

Connie Lynn Lazure, born September 24, 1948, attended the public schools of Halls, Tennessee. She graduated from Halls High School in May, 1966, and entered The University of Tennessee the following September. She received the Bachelor of Science degree in Food Science in December, 1970. From January, 1971, to the present, she has been a graduate student in the Department of Food Science and Institution Administration at The University of Tennessee, Knoxville. She is a member of the Institute of Food Technologists, the American Home Economics Association, Omicron Nu, and Phi Beta Alpha.