AN ABSTRACT OF THE THESIS OF

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ABSTRACT APPROVED:
Dr. Zoe Ann Holmes

The objectives were to investigate the ability of a two-factor central composite rotatable design (CCRD), using cooking temperature (CT) and endpoint temperature (ET) as independent variables, to predict selected chemical, physical and sensory meat quality characteristics considered important by the industry, researcher and consumer alike. Response surface analysis (RSA) was used simultaneously to evaluate the nature of the responses obtained, with 13 CT-ET combinations for the various species being evaluated. A contour plot-response surface graphics program ("SURCON") was developed at Oregon State University during this research and applied to the evaluation of the data. Evaluation of the nature of the response surfaces formed a major part of the thesis. Fresh pork loin

roasts, frozen lamb loin roasts, turkey halves (breast and thigh meat), and control (conventionally processed) and treated (prerigor, pressurized) semitendinous beef blocks were used for heat treatments.

For pork, the dependent variables of heating rate (^{o}C/min); evaporation loss (%); cooking time (min); total moisture (%); total nitrogen and "remaining" protein fraction (dry weight basis); chromaticity coordinate, z; and sensory panel juiciness, were significant and the CCRD was successful.

For lamb, the dependent variables of heating rates (^{o}C/g; ^{o}C/min); total cooking, drip and evaporation loss (%); cooking time (min); total moisture (%); expressible moisture index; total nitrogen (wet weight basis); chromaticity coordinate, x and z; saturation index and sensory panel doneness and color were significant.

For turkeys, the dependent variables of heating rates (^{o}C/g, ^{o}C/min, ^{o}C/g/min), total cooking and evaporation loss (%), cooking time (min), total nitrogen, low ionic strength and "remaining" protein fraction (dry weight basis) and non-protein nitrogen extract (wet weight basis), and sensory panel thigh juiciness were significant and the CCRD was successful in its ability to predict significant dependent variables.

The CCRD and RSA of pre-rigor pressurized beef beef were affected differently by CT-ET combinations than control processed beef.

PREDICTION OF MEAT QUALITY CHARACTERISTICS USING A TWO-FACTOR QUADRATIC CENTRAL COMPOSITE ROTATABLE DESIGN WITH RESPONSE SURFACE ANALYSIS

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Chapter 1

INTRODUCTION

Over the last decade a variety of meat and poultry production improvements have been reported for both red meats (Berry and Cross, 1982; Berry and Kotula, 1982; Riffero and Holmes, 1983; Thomas et al., 1981; Møller et al., 1983; Smith et al., 1976; Smith et al., 1970) and poultry (MacNeil et al., 1979; Unklesbay et al., 1983). Additionally, published literature has a large number of reports on processing and preparation influences on yield and quality of meat and/or poultry; however, the results of these investigations are generally unique and specifically applicable to the experimental conditions under investigation. There has been an interest in broadening the implications of the results of any given experiment. This interest is especially reflected in several recent papers concerned with product optimization through sensory analysis (Giovanni, 1983; Schutz, 1983; Sidel and Stone, 1983; Korth, 1982).

However, similar techniques have been utilized with specific research projects covering a wide range of food items. It would be most beneficial if efficient, cost effective experimental designs for the study of meats were to be applied to evaluate optimum yield, nutritional and esthetic qualities and various production, processing and preparation stresses.

The goal of this research project was to evaluate a variety of variables which indicate quality of meat and poultry as influenced by preparation stresses to determine if it is possible to predict characteristics. The applicability of these individual variables as predictors of quality within and between meat species was analyzed. Additionally, the feasibility of using the cost effective central composite rotatable design for research experiments was evaluated. This aim was accomplished through the undertaking of the following objectives in order to:

1) evaluate the applicability of the pork, lamb, turkey and beef studies to the central composite rotatable design;

2) analyze the predictive validity of selected variables and test for composition and quality determination of meat and poultry using the effective combination of a central composite rotatable design with response surface analysis; and where relevant, to find optimal regions, points or reactions, or to simply evaluate the response surfaces found and then attempting to account for them for all four species; and

3) assess the tenderness, doneness, juiciness, color and/or flavor of the meats by objective and subjective tests in pork, lamb, turkey and beef to determine the effects of preparation.

Response Surface Methodology, Two-Factor Central Composite Rotatable Designs and Response Surface Analysis

During the past 15-20 years scientific food literature has made frequent reference to concepts and techniques such as "response surface methodology;" "surface response analysis;" "response surface analysis;" "optimization" (Montecalvo et al., 1984); "optimization techniques" (Nakai, 1982); "predicted optimal combinations" and "optimal biological responses" (Roush, 1982); "optimization of ingredient levels" (Johnson and Zabik, 1981); "central composite rotatable designs;" or "rotatable central composite designs" (Myers, 1971, p.152).

There is a wide diversity of fields presently using response surface analysis (RSA) to explore, investigate, explain, evaluate, optimize (find optimum combinations), or to predict. This technique is reported in areas ranging from chemical engineering, especially with reference to the yield of chemical reactions and processes (Box and Hunter, 1957, and Hill and Hunter, 1966), to the lumber industry (Hailey et al., 1980). Perhaps more applicable to the area of interest in this thesis, is the extensive reporting of analysis and utilization in animal (Villasmil et al., 1975) and poultry (Roush et al., 1979) nutrition, seed germination studies (Evans et al., 1982) and post-harvest treatment of papayas (Hundtoft and Akamine, 1971). As can be determined by these references and the food-related summary in Table 1.1, response surface methodology (RSM) has been used to develop optimum formulae and to evaluate characteristic or functional properties. More recently, there has been more specific emphasis on sensory evaluation (Henika, 1982); whereas, previously this aspect was included in research and development reports (Henika, 1972; Bodrero et al., 1981; Fishken, 1983; Korth, 1982; Giovanni, 1983).

Two categories of literature appear to be prevalent, those written by the statistician for the professional (Box and Wilson, 1951; Box, 1954; Hill and Hunter, 1966; and Myers, 1971) and those written to be understood or followed by lay-persons or non-statisticians who are interested in understanding more about response surface methodology (RSM) (Giovanni, 1983; Korth, 1982; and Henika, 1972).

Terminology confusion

As a new and rapidly developing field, it has become increasingly difficult to interpret what is being meant since each author emphasizes certain aspects or words. Some of the confusing terminology includes "contour plots," "contour surfaces" (Roush, 1982 and Johnson and Zabik, 1981), two-dimensional plots and two-dimensional contours (Roush, 1982), "two-dimensional response surface" and "response surfaces" and "response contour representation of the relationships between ..." (Roush, 1982), and response contours, response maps and contour maps (Gacula et al., 1984). All

Table 1.1. Selected food-related literature utilizing response surface analysis.

AUTHORS AND YEAR	TITLE OR EMPHASIS
Aguilera and Kosikowski (1976)	Soybean extruded product: a response surface analysis.
Bodrero et al. (1981)	Evaluation of the contribution of flavor volatiles to the aroma of beef by surface response methodology.
Deng and Tomaszewski (1979)	The use of response surface methodology to determine the effects of salt, tripolyphosphate and sodium alginate on the quality of fish patties prepared from minced fish, croaker.
Fishken (1983)	Emphasizes "consumer-oriented product optimization" brings the consumer into the product development and product improvement process at an early stage.
Giovanni (1983)	Discusses RSM and product optimization together with sensory evaluation.
Henika (1982)	Use of response-surface methodology in sensory evaluation.
Henika (1972)	Simple and effective system for use with response surface methodology.
Henselman et al. (1974)	Use of response surface methodology in the development of acceptable high protein bread.
Korth (1982)	States "sensory evaluation strives to predict."
Lah et al. (1980)	A response surface methodology approach to the optimization of whipping qualities of an ultra-filtered soy product.

Table 1.1. Selected food-related literature utilizing response surface analysis (continued).

AUTHORS AND YEAR	TITLE OR EMPHASIS
Lane (1983), (p. 181)	Formulation variables affecting the flavor of extruded snacks and crackers, reporting the use of surface response methodology (SRM) for predicting the best combination of the various ingredients - "interactions among grain composition, internally and externally applied flavors in an extruded snack and the effect of fat composition and flavor in a snack cracker."
Li-Chan et al. (1984)	Hydrophobicity and solubility of meat proteins and their relationship to emulsifying properties.
Martin and Tsen (1981)	Baking high-ratio white layer cakes with microwave energy.
Nielsen et al. (1973)	Four factor response surface experimental design for evaluating the role of processing variables upon protein denaturation in heated whey systems.
Pearson et al. (1962)	Application of surface-response methodology to predicting optimum levels of salt and sugar in cured ham.
Sefa-Dedeh and Stanley (1979)	Cowpea proteins. 1. Use of response surface methodology in predicting cowpea (<u>Vigna unguiculata</u>) protein extractability.
Smith et al. (1977)	Physical stability of milk fat emulsions after processing as evaluated by response surface methodology.
Sullivan et al. (1981)	Carrot dehydration - optimization process studies on the explosion-puffing process.
Townsend and Nakai (1983)	Relationships between hydrophobicity and foaming characteristics of food proteins.
Voutsinas et al. (1983)	Relationships of hydrophobicity to emulsifying properties of heat denatured proteins.

of these refer to the same basic concept, called two-dimensional contour plots or contour plots by this author. Additionally, response surface contours (Roush, 1982), three-dimensional plots and "perspective response surfaces" (Johnson and Zabik, 1981) are also used as synonyms (here usually referred to as three-dimensional response surfaces). Other frequently encountered words and phrases are "response surface equations" (Johnson and Zabik, 1981); quadratic regression models, quadratic (second order) regression; polynomials (Cornell and Deng, 1982), and "simplex-centroid designs" (Cornell and Deng, 1982; Soo et al., 1978 and Toyomizu et al., 1982).

Furthermore, the term "parameters" not "variables" (Li-Chan et al., 1984; Evans et al., 1982; Bishop et al., 1981; Hailey et al,. 1980; and Soo et al., 1978) is also often used when reference is being made to dependent variables. In Hill and Hunter (1966) mention is made of response "variables" as including yield, temperature, pressure, and pH; whereas, "parameters" refer to functions such as reaction rate constant and heat transfer coefficient. Gacula et al. (1984) even used the term "parameters" when referring to regression coefficients. This tends to be confusing to those who prefer to think of population (not sample) means (mu) and population variance (sigma) as "parameters."

Giovanni (1983) defines the terms used in her paper as "factors," "levels" and "response." Even if they are slightly different to the terminology used in this thesis, they were at least explained clearly. "Factors" were defined as the characteristics of the product that can be varied within the specific system, for example, ingredient levels. "Levels" or "factor levels" were the quantity of the factors, for example, percent salt (amount of time the can is in the retort); and "response" was the effect of the different factor levels on the product under study, for example, taste intensity of the salt flavor in a bacon project. "Factors" and "levels" refer to the independent (X-) variables and "responses" to the dependent (Y-) variables.

Independent and Dependent Variables

In this thesis, the term "independent variable" is used synonymously with "controlled variable" or X-variable, and the "response" is used synonymously with "dependent variable" or the Y-variable. The terms "response variable" or "dependent variable" or "Y-variable" are used synonymously with the accepted abbreviation "$\hat{y}$" or "y-hat" or "estimated response" value. For clarification during the discussion of the current experiment, the author prefers to refer to the independent variables by their actual names: cooking temperature, or CT, for X1; and endpoint temperature, or ET, for X2, respectively. This is followed by "$\hat{y}$" designating the specific response variable or predicted, dependent variable under discussion. When the general multi-purpose interactive computer graphics program, SURCONN, is used, the X1, X2 and Y variables are referred to as X, Y and Z respectively. This is yet another example of how inconsistencies occur.

Uses and advantages of Response Surface Methodology

In general, response surface methodology (RSM) tests several variables simultaneously, uses special designs to cut down cost and time, and measures a number of effects by objective tests (Henika, 1982). Due to advances made in experimental design and analysis, the researcher is able to investigate interrelationships among several quantitative (X) variables in an effort to maximize a response, for example, growth in poultry (Roush, 1982). The important difference between this approach and the traditional "one variable at a time" approach is that the computer takes the experimental results and calculates the models using Taylor second order quadratic equations. These equations define the relationships between variables and responses (Henika, 1982). A great advantage of RSM as applied to product development is that it helps one to understand simultaneous interactions between ingredients in the product. This results in a greatly improved product as well as a substantial saving of time and money (Giovanni, 1983). Fishken (1983) points out that companies routinely utilizing optimization procedures need less repeated consumer testing as it provides a level of certainty about the level of success of the product formulation. In explaining why RSM is more efficient in solving product development and improvement problems than classical approaches of testing one variable at a time, RSM is defined as "a statistical method that uses quantitative data from appropriate experimental designs to determine and simultaneously solve multivariate equations" (Giovanni, 1983, p.41). These multivariate equations specify the optimum product for a given set of factors through mathematical models. These models consider interactions among the test factors and can be used to determine how the product changes with changes in the factor levels (Giovanni, 1983, p.83). Thus, three major uses of RSM emerge from the mathematical model approach. RSM helps to determine: the best combination of independent variables which will result in a desired response and thereby describe the response near the optimum; how a particular response is affected by changes in the independent variable values being considered; and the levels of the independent variables that will simultaneously satisfy a particular set of criteria. Giovanni (1983) further reviews how these mathematical equations can be graphically or visually represented as contour and/or three-dimensional response surfaces which, in turn, can be utilized to describe how the variables being tested influence the response or determine the interrelationships among the test or X-variables.

Key Concepts in Designs

Since response surface methodology (RSM) is "a statistical method that uses quantitative data from appropriate experimental designs to determine and simultaneously solve multivariate equations" (Giovanni, 1983, p.41), discussion of some of these designs and related concepts is critical to further understanding. Several selected designs of particular importance in RSM development for this and other investigations are reviewed and discussed. The choice of design is critical, as the design will influence whether the advantages inherent within RSM can be gained from the data.

RSM was originally developed and described by Box (a statistician) and Wilson (a chemist) in 1951 although Mead and Pike (1975) refer to important contributions to this field of study as found in the "pre-Box era." In 1951 Box and Hunter used Taylor First and Second Order equations in a sequential testing procedure that is called the "Path of Steepest Ascent" (Henika, 1972). It is difficult to find a clear and comprehensive classification of designs and techniques applicable to RSM. Nakai (1982, p.145) compares the "modified super-simplex optimization" with various statistical methods and designs, including "central composite rotatable designs of response surfaces." The phrase "optimization techniques" appears to be used synonymously with "RSM." Regression is used and response surfaces are examined, as pointed out under the uses of RSM. It would, therefore, seem correct to state that response surface methodolgy includes these types of designs too. Toyomizu et al. (1982) refer to "perspective views," contour maps and cross-sectional views of the response surfaces obtained when multiple regression models are used. Multiple regression and RSA, therefore, appear to go together.

Box and Wilson (1951) discuss experimental designs that are aimed at finding the point on a response surface at which the maximum yield is attained, using the smallest number of observations. They also introduced the concept of "composite" designs for the first time. In composite designs a range of values for one or more statistical "parameters" are specified. The main assumption of Box and Wilson's 1951 paper is that a polynomial can be used to approximate a response through the choice of the levels of the various treatment factors involved.

Central Composite Designs (CCDs) and Rotatability

Hill and Hunter (1966) point out that the main papers dealing with central composite designs and the concept of rotatability for RSM are by Box and Wilson (1951), Box and Hunter (1957), and Myers (1971).

Figure 1.1 illustrates the difference between a central composite design (Fig. 1.1A) and a non-central composite design (Fig. 1.1B). Figure 1.2 shows an application, called a central composite rotatable design (CCRD) (Cochran and Cox, 1957).

Composite designs are defined as "first-order factorial designs augmented by additional points to allow estimation of the coefficients of a second-order surface" (Myers, 1971). The central composite design is the 2^k factorial or fractional factorial augmented by various combinations of the "0" and positive or negative alpha values, where the value of the alpha is selected by the experimentor (Myers, 1971, p.127).

In the work being reported here, a two-factor central composite rotatable design (CCRD) (Fig. 1.2) was used. Using the description by Cochran and Cox (1957), Fig. 1.2 is a design for two independent or X-variables and may be subdivided into three parts, namely: (1) the four points (-1,-1), (1,-1), -1,1), and (1,1) which constitute a 2^2 factorial; (2) the four points (-1.414, 0), (1.414, 0), (0, -1.414), and (0, 1.414) which are the extra points included to form a central composite design with alpha = the square root of 2 = 1.414. These four points form the "star" figure shown in the design; (3) five points are added at the center of the design to "give roughly equal precision for $\hat{y}$ within a circle of radius 1" (Cochran and Cox, 1957, p.347). The replicated points in the center provide (n-1) degrees of freedom for estimating the experimental error, determining the precision of y-hat ($\hat{y}$) at and near the center (Cochran and Cox, 1957). Too many replications at the center point causes the standard error of the predicted dependent variable response, y-hat, to be low

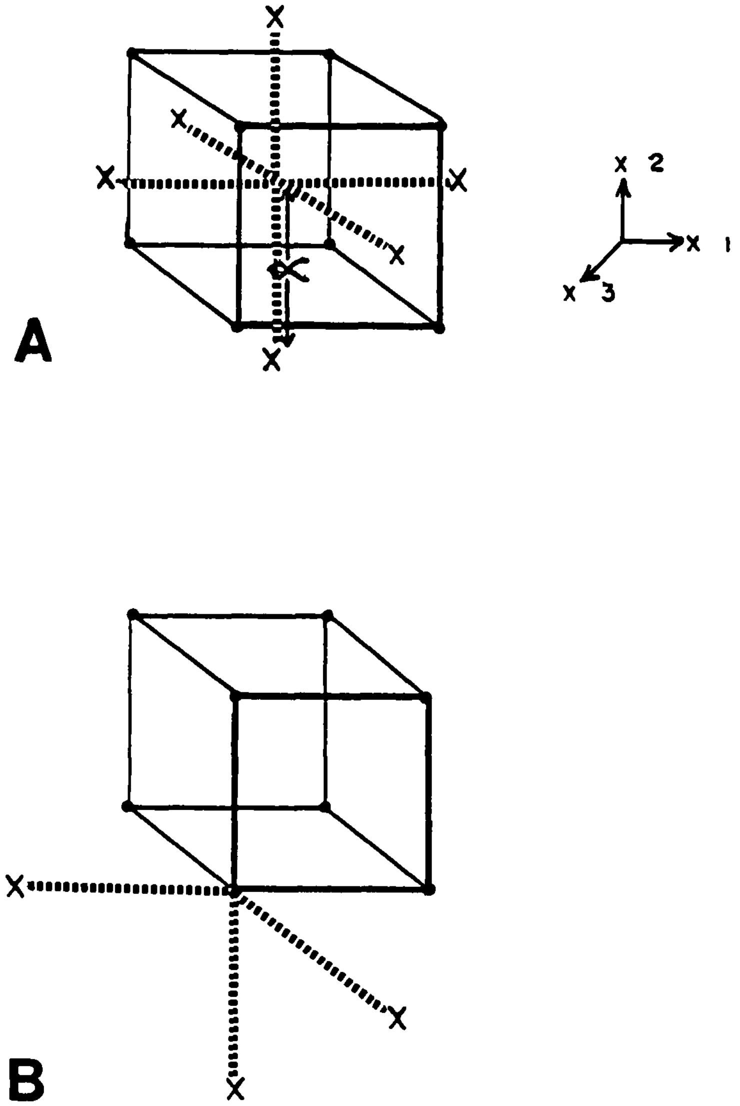

Fig. 1.1. Central composite design (CCD) for three factors (A, after Box, 1954, p. 34) and non-central composite design for three factors (B, after Cochran and Cox, 1957, p. 344).

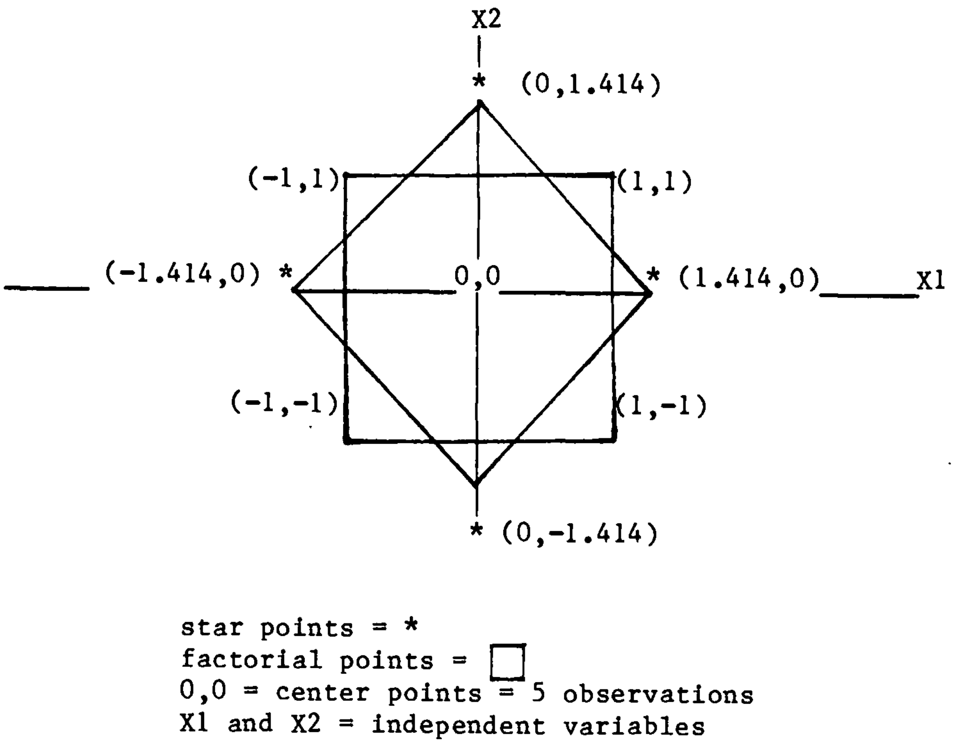

Fig. 1.2. The basic central composite rotatable design (CCRD) for two X-variables (Cochran and Cox, 1957, p.346).

at the center and to increase rapidly as one moves away from the center. Alternatively, with only one or two center points, the standard error of y-hat may be greater at points like (1,0) or (0,1). Box and Hunter (1957) compromise by suggesting that the number of center points be chosen in such a way that the standard error of y-hat is approximately the same at the center as at all points on the circle with radius one. When this choice is made, "the standard error remains roughly the same at all points within the circle of radius one" (Cochran and Cox, 1957, p.346). This relates to the "rotatability" of the design, as will be further described. Rotatable designs of any number ("k") of the X-variables can be built up from these three components. The value of alpha must be $2^{k/4}$ for the design to be rotatable. In this current investigation, two independent variables were used, so that alpha = $2^{2/4} = 2^{0.5} =$ 1.414. Cochran and Cox (1957, p.347) give a table showing the values for the components of a central composite rotatable design (CCRD) for k = 3,4,5 and 6. For the two X-variables (k = 2 levels), the number of points in the 2^k factorial is $2^2 = 4$, the number of star points = 4, the center points = 5. The total number of observations is, therefore, 13 with the alpha (or circle's radius) value = 1.414. In this design complete randomization of the experimental order is assumed.

Myers (1971) points out that an important property of response surface designs is that of rotatability. This concept of rotatability is not restricted to second order designs, but much of the work reported on this subject relates to the fitting of the second order model. A design is said to be rotatable when the variance of the estimated response - that is, the variance of y-hat, which of course depends on a point of interest x_1, x_2,.....,x_k, is a function only of the distance from the center of the design and not the direction. In other words, a rotatable design is one for which the quality of the estimator y-hat is the same for two points that are the same distance from the design center (Fig. 1.2). Mead and Pike (1975) agree with this description.

Simplex-centroid designs

Central composite designs and central composite rotatable designs are only two of the designs to which the RSM technique can be applied. A third general category is simplex-centroid designs. Cornell and Deng (1982) referred to lattice arrangement designs introduced by Scheffé (1958, 1963) and reviewed the use of statistical designs formed by combining these simplex-centroid designs in ingredient or mixing experiments with factorial arrangements. The three components result in the simplex space being a triangle whereas four components result in a tetrahedron. Quadratic or cubic regression analysis is used to mathematically model the response behavior and, by including both types of variables, namely mixture ingredients and process variables, more information can be obtained, leading to a greater understanding of the combined system. Soo et al. (1978) also refer to Scheffé (1963) in using a simplex-centroid design to study the effect of processing (mixing time, temperature) and compositional (shrimp, isolated soy protein, NaCl, sodium tripolyphosphate) variables on the textural changes of fabricated shrimp.

Visual representations of response surface methodology

Each of these three experimental designs will furnish the appropriate mathematical data to visually represent the relationships observed if a suitable computer-graphics program is chosen. It is important for the researcher, scientist, engineer or product developer to be able to translate and communicate his/her findings to the public and/or management decision makers (Thompson, 1983). The ability to do this is greatly enhanced by the use of two-dimensional contour plots and three-dimensional response surfaces, once the basic principles involved are understood. If more than one response is being examined, contour plots can be constructed for each one, and then they can be examined by placing them side-by-side or superimposing them to ascertain the optimum areas. It is important to remember that "contour plots are, of course, not exact but only estimated representations of the true surface" (Hill and Hunter, 1966, p. 575).

The nature of the contour plots. The term "response surface analysis" (RSA) implies that the results are evaluated with the aid of two-dimensional contour plots and three-dimensional response surfaces. Myers (1971) states that a first order regression model is useful when one is interested in studying narrow regions of x_1, x_2 ....,x_k where little curvature is present. Alternatively, the experimentor might use second order functions. These second order functions have been determined by the current investigator to be applicable to some meat quality predictions. Once the surface is fitted with this quadratic regression equation, the most meaningful way of interpreting the results is by plotting response contours and three-dimensional response surfaces. The contour plots may be calculated by computer or by hand and, in the latter case, the contours drawn in by hand (Roush et al., 1979). Mead and Pike (1975) consider situations where the response or dependent ("yield") variable changes according to some pattern in response to the levels of one or more controllable ("stimulus") variables. Time may also be included as one of these X-variables. This "pattern of variation" implied in the contour plot is made more visual when in the form of a 3-dimensional response surface or response curve.

The term "response surface" was coined to describe the relationship found when two independent variables ($k = 2$) appeared on the scene. Then a 1-dimensional diagram (as for $k = 1$) where the response is a line was no longer helpful in explaining what was happening. If one wishes to observe graphically what the surface (estimated response function) looks like, and one is working with a second order (quadratic) response function, one can have a computer draw or plot "contours of constant response" (Myers, 1971, p.63) or so-called two-dimensional contour plots. Instead of plotting the response on the vertical axis and the independent X-variable on the horizontal axis, there are 2 X-variables plotted, one on each axis. Early in the planning stages, the choice of the design points (factor levels) is important. The coefficients in the regression models (A through F in this thesis) are estimated (computed) from the data obtained by the experimentor in the laboratory, using suitable statistical analysis procedures, for example, quadratic regression. These coefficients are used for two-dimensional plots and three-dimensional surfaces.

The analysis of the estimated response function is often referred to as the analysis of the "fitted surface." This analysis is accomplished through use of least squares estimation procedures, often augmented by mathematical techniques that look for maximum, minimum and stationary points (Myers, 1971). It is usually desirable to know the maximum or minimum value of the response, y-hat ($\hat{y}$). The mathematical procedure carried out by the computer involves matrix algebra and elementary calculus (Roush et al., 1979 and Myers, 1971). One should never extrapolate outside the experimental range (Myers, 1971) when evaluating the response surface. When the model equation chosen for use is an "adequate representation in the region of interest," the analysis of the fitted surface approximates the analysis of the actual physical system (Myers, 1971, p.64). Contour plots are just like two-dimensional topography (land) maps of mountainous areas, as it is the topography of the surface or area or response that is being explored. The contour lines (or "contours") drawn on the map indicate the responses attained and each line joins like values found along the matrix of calculated or computed values (Henika, 1972). The contour plots and corresponding three-dimensional response surfaces can be classified into five groups, namely, hills, troughs, saddles, stationary and rising ridges.

Hills, troughs and stationary points or regions. If the area being explored has a definite maximum region or point, it is like a hill or "mound" (Fig. 1.3A, 1.4C and 1.4D), and this region might be a definite "point" or be circular (Fig. 1.4A and 1.4B) or ellipsoid (Fig. 1.3A, 1.4C and 1.4D), if one has chosen the optimum response. If one moves in any direction, one's response values decrease. If one encounters a region of minimum response, it resembles a valley, a

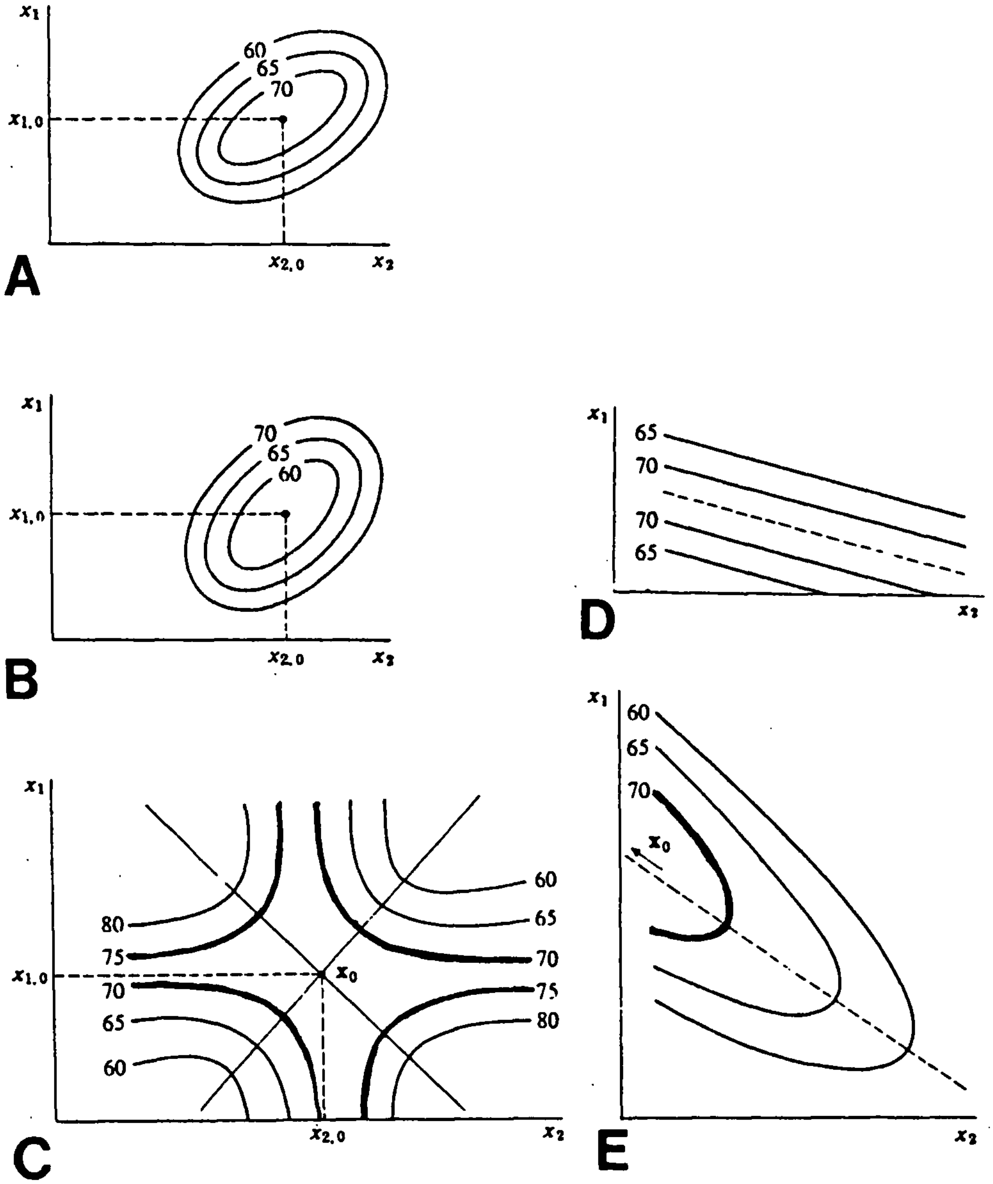

Fig. 1.3. Examples of fitted surface analyses with hills (A=maximum point), troughs (B=minimum point), saddles(C=saddle point), stationary ridges (D=stationary ridge system), and rising ridges (E=rising ridge system), showing stationary points (xo) (after Myers, 1971, pp. 70-71).

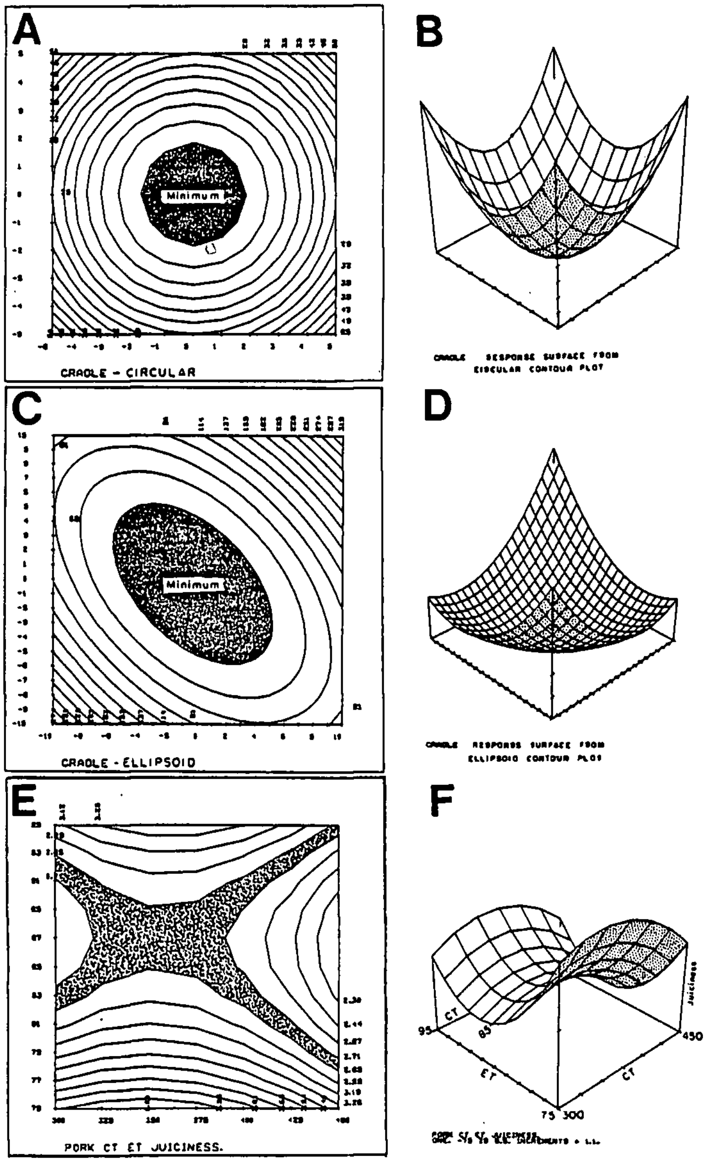

Fig. 1.4. Examples of contour plots of circular (A, dotted) and ellipsoid (C, dotted) cradles and the respective response surfaces (B, D) and a saddle contour plot (E, shaded) and corresponding response surface (F) for pork juiciness. (Undersides of surfaces are dotted.)

trough, or a V-shaped cone, depending on how gradual or steep the sides are (Fig. 1.3B). If one moves away from the minimum, then the responses increase.

Myers (1971) gives a detailed description of "stationary points" (called "x_o"), although it must be emphasized that these points do not necessarily denote the maximum or minimum points of the response, as they might sometimes better be described as regions. Roush et al. (1979) emphasizes calculating the stationary point before examining the three-dimensional response surfaces and describes it as the point where the slope of the surface is zero. The stationary point may represent the maximum or the minimum point of the fitted surface, or it may also be the point at which the surface is a saddle point or a minimax.

Saddles. A saddle point or minimax is a minimum point for one variable and a maximum for another (Fig. 1.3C). The stationary point or region might also fall in the shape of a saddle (Fig. 1.3C). Box (1954) also refers to this saddle point as a "col" or a "minimax." In this case it is interesting to see in which direction one has to move in order to attain an increase in response. This would be done if the researcher were interested in locating the greatest possible response area.

Signs and nature of the stationary areas. Box (1954) also draws attention to the nature of the surface and the signs on the coefficients. The nature of the surface can be quickly determined by noting the signs of the squared coefficients of the model:

$$\text{Y-hat} = A + B*CT + C*ET + D*CT*CT + E*ET*ET + F*CT*ET.$$

One might check upon the correctness of the response surfaces drawn by computer, by observing the signs of the D and E squared term coefficients, using the criteria below:

Coefficients		D	and	E	
If	=	neg.	and	neg.	= maximum
if	=	pos.	and	pos.	= minimum
if	=	pos.	and	neg.	= minimax
if	=	neg.	and	pos.	

The minimax situation needs more investigation, as proven by the data generated by this project. Mullen and Ennis (1979) agree.

Stationary and rising ridges. Other possible and rather special situations are encountered in the "stationary ridge" (Fig. 1.3D) and the "rising ridge" (Fig. 1.3E) systems - these are definite regions not points. In the case of the rising ridge system, the actual stationary point falls outside the area tested. If there is a falling ridge system, then naturally the response falls when one moves towards the stationary point or region.

This information relates directly to the CCRD used in this project and its contour plots. Box (1954) discusses similar fundamental contour plots that have been generated by a quadratic regression equation. He regards the contour diagrams like Fig. 1.3A, 1.3B and 1.3C as being fundamental surfaces and Fig. 1.3D and 1.3E as being "limiting" surfaces.

Interpretation problems. Giovanni (1983) in describing the four steps involved in RSM (Fig. 1.5), also mentions the interpretation of the response surfaces, pointing out that interpretation is not always easy to do. If a cradle (or bowl) is generated as the response surface (Fig. 1.3A, 1.4A and 1.4B), then the optimum response lies along the top edges, not where the lowest point is. A saddle point has the optimum response along the sides, or perhaps in each of the four corners. Therefore it is not easy to evaluate in terms of optimum amounts to use for the best product (Fig. 1.4E and 1.4F). This author differs slightly in terminology, as the "optimum" value does not necessarily have to be the "maximum" value - it may be a minimum value, or it may even be the saddle's "valley-value" itself. For example, in evaluating the sensory panel's results for pork loin roast juiciness, using a score of 1 = very tough and 5 = very tender, the "not-dry-not tough" value fell in the middle, at value 3. If the mean score for the panelists falls around 3, then a saddle will result and the "valley" will be the optimum value. Giovanni (1983), in a discussion of saddles pointed out that it would be more correct to say "a saddle point has the maximum value along the sides or perhaps in each of the four corners, if one is considering values like percentages, with 10 percent considered lower in value than, say 80 percent." When evaluating percent retention versus percent lost, maximum percent retained is minimum percent lost. If the top area of the saddle represents percentage vitamin retention, then it is indeed an "optimum." On the other hand, if one is considering percent vitamin lost, then the minimum value in the valley is optimum and more desirable, as one wants as little as possible lost. The independent variable combinations resulting in this response are then most desirable or "optimum."

Planning for RSM use

Before embarking upon a particular RSM application or experiment, one needs to be aware of existing guidelines for the planning stages.

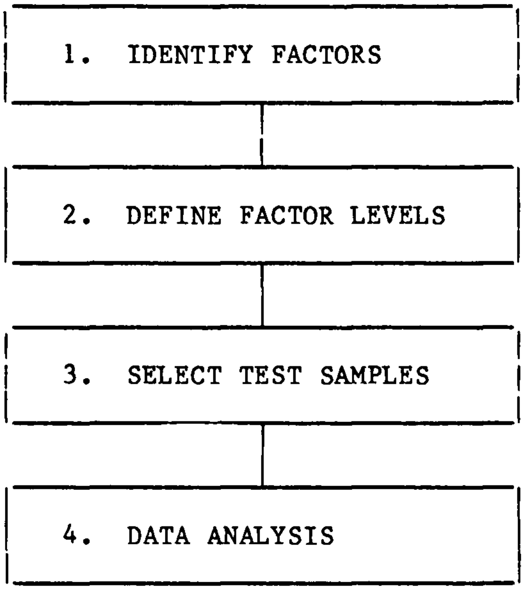

Fig. 1.5. The four-step response surface analysis (RSA) process according to Giovanni (1983).

This is well introduced and explained by the diagramatic outline (Fig. 1.5) and details of this four-step process are put forward by Giovanni (1983, p.41).

Identifying factors. First, in identifying factors or independent variables, one should decide on two or three critical factors (independent variables) that are considered most important to the product being tested, including the factor that will account for the most variation in the product. When these factors are not known, preliminary studies must be done to identify them.

Defining factor levels. The next step is defining the factor or independent variable levels. It is important to choose factor levels which will cover the physical specifications of the product or sample being tested. If these ranges or amounts are too broad and the sought-after optimum is not clearly defined or included by RSM, then a second RSM experiment can be run, using a narrower range of levels. It is possible that, at times, the specific optimum may fall outside the levels tested, but due to cost, physical limitations and government regulations one may not be allowed or otherwise able to explore those areas or regions.

Selecting test samples. One should select test samples according to the statistical design chosen. Giovanni (1983, p. 42) describes this set of samples as a selected "subset" of all the possible ones which could be evaluated. These designs cover or test over the whole range specified, but they emphasize the samples closest to the midpoints of the ranges chosen. Being a subset, they therefore also decrease the total number of samples to be tested. Experiments are conducted to test the samples and quantitative data or results are thus obtained and used in the subsequent statistical analysis. These data may be sensory responses (descriptive and acceptance), physical measurements (for example, viscosity), chemical analyses (such as, TBA number), microbiological assays, and processing information (for example, time, temperature).

Analyzing data. The fourth and probably the most important step is data analysis. The data from these results are analyzed by RSM and the plots interpreted. This analysis is best done using an appropriate computer program. It is more important than ever that all the people involved with the data collection should cooperatively interpret the results. There is a need to follow up on the conclusions, and care must be taken not to extrapolate the results beyond the scope of the specific study.

Assumptions and limitations to consider when using RSM

1) Assumptions. In developing a specific RSM, there are also five assumptions by Giovanni (1983) that must be taken into account simultaneously with the four steps (Fig. 1.5). It is assumed that the factors (independent variables) which are critical to the particular product are known, that the area of major interest (where the factor or independent variable levels are most influential) is known, that the independent variables vary continuously throughout the range tested, that there is an available mathematical function which relates the independent variables to the measured response to use, and "the response which is defined by this function is a smooth surface" (Giovanni, 1983, p. 42). With reference to the penultimate assumption, Korth (1982)'s original rules include the fact that regression always fits a suitable model (for example, linear or

quadratic) to one's data. It naturally implies that both the model and the data are required. Korth (1982) warns against making data transformations as this often results in problems of interpretation.

2) Limitations. With the above-mentioned assumptions, Giovanni (1983) also warns that there are certain limitations with RSM. Large variations in the so-called factors or independent variables can lead to misleading conclusions. This variation within these independent variables might be caused by experimental error or else bias due to the test procedures. Variation should be decreased by designing the experiment so as to control all sources of variation possible. By increasing the number of replications one can also decrease variability. It is also possible that the critical independent variables of the product or sample may not have been correctly identified, specified or completely defined, resulting in an inaccurate description of the optimum product. It may not be possible to determine the optimum product by using RSM, because the range of independent variable levels tested was either too narrow or too broad to specify the optimum. The success of defining the optimum product depends upon the selection of appropriate independent variable levels within the given limitations.

RSM is sensitive to the misuse of basic statistical principles as failure to attend to them will result in an incorrect mathematical model being used to describe the optimum or maximum response. The experimentor is expected to use good judgement and have sufficient knowledge about the product, in order to be able to draw appropriate conclusions from the data. Korth (1982) lists six additional rules of regression which are pertinent here, namely, that one should never use redundant predictors, one should avoid highly correlated predictors, never use many predictors, avoid using proportions as predictors, always use an intercept in one's model unless one has a strong reason for not doing so and always test one's results.

Korth (1982, p.91) also points out some other possible interpretation problems. One may have numerous predictors but only one "criterion" so that if one attains significance for a particular response, it means that the sample size was large enough and not that the model was important. Korth (1982, p.91) also makes the following comments: One absolute rule of selecting predictors (Y-variables) is that each predictor must be measured independently of the others. One should not measure two predictors and then include the weighted sum or difference as the third. Ratios are all right but proportions are not. Products are also not acceptable. One must justify the addition (summing) of the predictors and use fewer predictors than the number of observations.

Conclusion

In conclusion, it may be emphasized that by utilizing available information on assumptions, limitations and the process of RSM, one can obtain differing outcomes with these techniques. Even though RS procedures are not primarily used to elucidate the mechanism of the underlying system or process, the use of these procedures may sometimes prove very useful in doing just that or even confirming previously obtained conclusions. The major purpose of RSM "is to determine what the optimum operating conditions are or to determine a region of the total space of the factors in which certain operating specifications are met" (Myers, 1971, p.63).

Factors Influencing Meat Quality Characteristics

The focus of the research was on qualities of meat and poultry. Meat from beef, pork, lamb, and turkey species remain important sources of good quality protein and menu variety in the average, westernized diet of the United States of America, and in the author's country, the Republic of South African diet. The ability to predict meat quality successfully would be valuable for use in quantity food production and general industrial uses. For example, if one could predict the approximate percent total moisture retained or lost under a given range of heating conditions, anticipated yields could be more efficiently calculated.

Although this dissertation focuses on the use of a two-factor quadratic central composite rotatable design, a brief summary of factors of importance to an understanding of meat and poultry quality is appropriate. A selected number of classic papers and review articles are cited to permit the exploration of these areas in greater depth by the reader. Current articles can be located by utilizing the commercially available computerized information retrieval systems. The major portion of the meat and poultry related literature before 1978 can be located by utilizing a comprehensive "Bibliography of Selected References on Beef" (Holmes, 1978).

The composition and structure of the muscle is primarily responsible for the meat quality characteristics of tenderness, juiciness, color and flavor or taste. The composition (Table 1.2), including water, protein, lipid, ash and carbohydrates, varies both within and between those species used in this investigation. Both composition and structure have been extensively reviewed (Cassens and Cooper, 1971; Briskey and Fukazawa, 1971; Briskey et al., 1970). Additionally, more recent research has focused on the gel-forming ability of muscle proteins and has resulted in more detailed and biochemical insights into the structure of myosin (Ishioroshi, et al., 1982; Peng, et al., 1982 a and b; Samejima, et al., 1981; Rhee et al., 1984). A number of structural mechanisms have been clarified through the increased understanding of the molecular structures of the myofibrillar and collagen proteins. The relationship of gross muscle structure to molecular muscle structure shown in Fig. 1.6 summarizes the primary organization of myofibrillar proteins. Essentially, the muscle consists of a series of thick and thin protein fibers enclosed by a covering of connective tissue, interspersed with fat cells, nerves and blood vessels. As shown in Fig. 1.6, the structure is organized to contribute to the contractile mechanism (Forrest et al., 1975; Laakkonen, 1973; Huxley and Hanson, 1954) in the pre- and postmortem animal. In meat, the protein structural components are the major contributor to tenderness and juiciness, whereas, the sarcoplasmic myoglobin is the major contributor to color (Govindarajan, 1973). Flavor arises from a variety of volatile and nonvolatile components (Dwivedi, 1975).

The quality characteristics are influenced by a variety of interactions and stresses. Postmortem changes have been excellently reviewed by Asghar and Yeates (1978). The effect of a number of

Table 1.2. Moisture, protein, fat, total carbohydrate and ash content of pork, lamb, turkey and beef.

Description	Water %	Protein %	Fat %	Total CHO %	Ash %
Pork loin					
Fresh, separable, lean					
Raw	69.0	19.1	10.2	0	1.4
Roasted	57.2	28.0	12.9	0	1.9
Medium fat class					
Raw	57.2	17.1	24.9	0	0.9
Roasted	45.8	24.5	28.5	0	1.2
Lamb loin					
Prime, separable, lean					
Raw	71.8	19.8	6.8	0	1.6
Broiled	61.3	28.0	8.6	0	2.2
Choice, separable, lean					
Raw	72.6	19.9	5.9	0	1.6
Broiled	62.1	28.2	7.5	0	2.2
Turkey					
Light meat					
Raw	73.0	24.6	1.2	0	1.2
Roasted	62.1	32.9	3.9	0	1.2
Dark meat					
Raw	73.6	20.9	4.3	0	1.1
Roasted	60.5	30.0	8.3	0	1.2
Beef, round					
Separable, lean					
Raw	72.7	21.6	4.7	0	1.0
Broiled	61.2	31.3	6.1	0	1.4

Watt, B.K. and Merrill, A.L. 1963. Compositition of Foods, Raw, Processed, Prepared. Agriculture Handbook No. 8. Agricultural Research Service, United States of Agriculture, U.S. Government Printing Office, Washington, D.C. 20402.

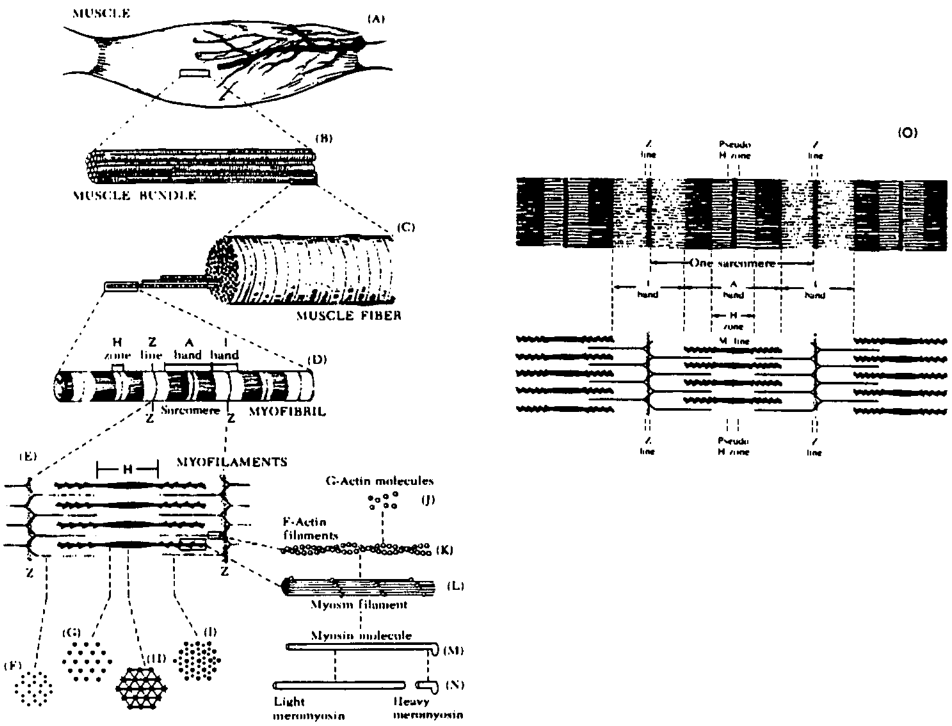

Fig. 1.6.[1] Diagram of the organization of skeletal muscle from the gross structure to the molecular level. (A) skeletal muscle, (B) a bundle of muscle fibers, (C) a muscle fiber, showing the myofibrils, (D) a myofibril, showing the sarcomere and its various bands and lines, (E) a sarcomere, showing the position of the myofilaments in the myofibril, (F-I) cross sections showing the arrangement of the myofilaments at various locations in the sarcomere, (J) G-actin molecules, (K) an actin filament, composed of two F-actin chains coiled about each other, (L) a myosin filament, showing the relationship of the heads to the filament, (M) a myosin filament showing the head and tail regions, (N) the light meromyosin (LLM) and heavy meromyosin (HMM) portions of the myosin molecule, and (O) portions of two myofibrils and a sarcomere and a diagram corresponding to the sarcomere, identifying its various bands, zones, and lines. [Modified after Bloom and Fawcett, A Textbook of Histology, 9th ed., W.B. Saunders Company, Philadelphia, p. 273, 1968.]

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[1] Fig. 1.6. adapted from Forrest, Aberle, Hedricks, Judge and Merkel, Pinciples of Meat Science, Freeman, San Francisco, California, pp. 32-33, 1975.

species and environmental variables (Armbruster et al., 1983; Miller et al., 1983; Holmes, 1978; Cassens et al., 1975) and handling and processing (Choi et al., 1984; Leak et al., 1984; Igbinedion et al., 1983; Koohmaraie et al., 1984; Prusa and Bowers, 1984; Mφller et al., 1983; Holmes, 1978; Cassens et al., 1975; Locker et al., 1975) factors have been reviewed or reported. Papers on the effect of postmortem storage on degradation of the myofibrillar protein actin (Lusby et al., 1983) and the effect of electrical stimulation on postmortem property changes of myofibrillar proteins such as the various troponin fractions, tropomyosin and heavy and light meromyosin chains (Kang, et al., 1983) also bring to light some of the complexities of regulatory proteins and finer sub-classes of the more well-known proteins.

Although other stresses are important, the effect of heating is of greatest pertinance for this brief review. Basically, heating will bring about a tenderizing of collagen; toughening of the myofibrillar proteins, actin, and myosin; and a translocation of water and fat. The decreased tenderness of the myofibrillar protein is due to the denaturation of actin. A shrinkage (Laakkonen, 1973) of the fiber occurs concurrently. Tenderness may increase with adequate heat application due to the breakdown of intermolecular and intramolecular collagen fiber bonds. Additionally, the collagen may shorten. Three distinct major changes (Bouton et al., 1976) occur in cooking of meat: initially the myofibrillar protein changes; next, the connective tissue shrinks and, lastly, there may be an interaction between connective tissue and myofibrillar protein.

The reviews emphasize the lack of agreement, understanding and precision as to phenomena and reactions which occur at specific temperatures with meat protein, water and fat. This is due to a variety of reasons. A considerable variation may be attributable to samples and the procedures which analyze for protein denaturation changes. Table 1.3 summarizes the changes which probably occur within the broad ranges of temperatures chosen (Hamm, 1966). This is presented in order to furnish basic information required for understanding some reactions which affected results in the current experiment. The figure emphasizes the major changes occurring. Recently reported work on the influence of heat on meats has focused on such areas as water loss rates and temperature profiles in dry heated normal and PSE pork muscle (Cloke et al., 1981); effects of cooking and chemical treatment on heme and nonheme iron in meat (Schricker and Miller, 1983); and turkey quality as affected by ovens of varying energy costs (McNeil and Penfield, 1983).

Table 1.3. Summary of physical and chemical changes of muscle during heating.

Temperature	Physical and Chemical Change
20-30°C	No changes occur in the colloidal-chemical properties of tissue or in the solubility and ion-binding of muscle proteins. Adenosine triphosphatase activity of myosin decreases at 30°C.
30-50°C	Changes in the myofibrillar proteins occur, influencing water-holding capacity and rigidity of tissue, solubility, pH, isoelectric point, number of easily available sulfhydryl groups and dye-binding acidic groups and the capacity of muscle proteins for binding Ca++ and Mg++. Adenosine triphosphatase is completely inactivated. Myofibrillar proteins changes include two steps: an unfolding of peptide chains and the formation of relatively unstable cross linkages resulting in a tighter network of protein. A small part of the sarcoplasmic protein is also denatured.
50-55°C	In this range of temperature a rearrangment of the myofibrillar proteins occurs causing a delay in the changes of water-holding capacity, pH, easily available dye-binding acidic groups and protein bound Ca++ and Mg++. New cross linkages begin to form which are quite stable and cannot be split by addition of weak base or acid. The denaturation of sarcoplasmic protein is continued.
55-80°C	Most of the changes occurring between 40°C and 50°C are continued to a lesser extent. At 65°C most of the myofibrillar and globular muscle proteins are coagulated. Collagen shrinks at temperatures around 63°C and may be partially transformed to gelatin at higher temperatures.
above 80°C	The formation of disulfide bonds by oxidation of the sulfhydryl groups of actomyosin begins between 70°C and 90°C and is continued with increasing temperature. Above 90°C H_2S is split off from the sulfhydryl groups of actomyosin. Further changes in the muscle proteins during heating to 120°C result in a decrease of dye-binding basic groups and protein-bound Ca++ and Mg++. Maillard reactions begin at about 90°C and are continued with increasing temperature and time of heating. Collagen is transformed to gelatin.

Modified from Hamm, R. 1966. Heating of muscle systems. IN: Briskey, E. J., Cassens, R. G., and Trautman, J. C. editors. "The Physiology and Biochemistry of Muscle as a Food". The University of Wisconsin Press, Madison, p. 381.

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Chapter 2

A SUMMARY OF NOTEWORTHY FEATURES OF A COMPUTER PROGRAM ("SURCON") FOR GENERATING CONTOUR PLOTS AND RESPONSE SURFACES[1]

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SURCON

(submitted to Food Technology)

ABSTRACT

A SUMMARY OF NOTEWORTHY FEATURES OF A COMPUTER PROGRAM ("SURCON") FOR GENERATING CONTOUR PLOTS AND RESPONSE SURFACES. I.B. ZONDAGH AND Z.A. HOLMES, Department of Foods and Nutrition, Oregon State University, Corvallis, OR 97331.

There is a present emphasis on the use of response surface analysis (RSA) in food-related fields. A brief tabulated review pointing to a general lack of information concerning relevant graphics programs used in the literature precedes the description of Oregon State University contour plot-response surface graphics program "SURCON." This program description serves to present potential RSA users and computer programmers with requirements and capabilities useful for their program. Major features and improvements of this user-friendly interactive program are mentioned and future prospects are listed using program-plotted examples.

INTRODUCTION

Response surface methodology (RSM) is being increasingly reported in the food-related literature (Table 2.1) and symposia and meetings (IFT 84, 1984, 44th Annual Meeting). Food Technology has published a number of articles (Fishken, 1983; Giovanni, 1983; Henika, 1982; Korth, 1982; Mullen and Ennis, 1979; Schutz, 1983; and Thompson, 1983) emphasizing the use and interpretation of this technique. However, the evaluation of these and other selected articles emphasizes the need for a presentation of some of the actual procedures and programs utilized in obtaining the graphics required for RSM interpretation. This paper presents sample problems using a successful program available from Oregon State University. For the researcher or graphics programmer, the discussion on SURCON presents approaches and potential features which would be useful to incorporate into their own software. The capabilities with a program such as this SURCON are useful in many diverse fields, such as the eleven step computer optimization and response surface analysis stages of new product development as set out by Meyer (1984).

The limited number of programs cited in the literature are of varying flexibility and availability. A number of these programs (Table 2.2) include method(s) of response surface methodology (RSM), calculations and response surface analysis (RSA) 2-dimensional (2-D) plots and/or 3-dimensional (3-D) surfaces.

Table 2.1. Selected food-related literature utilizing response surface analysis.

AUTHORS AND YEAR	TITLE OR EMPHASIS
Aguilera and Kosikowski (1976)	Soybean extruded product: a response surface analysis.
Bodrero et al. (1981)	Evaluation of the contribution of flavor volatiles to the aroma of beef by surface response methodology.
Deng and Tomaszewski (1979)	The use of response surface methodology to determine the effects of salt, tripolyphosphate and sodium alginate on the quality of fish patties prepared from minced fish, croaker.
Fishken (1983)	Emphasizes "consumer-oriented product optimization" brings the consumer into the product development and product improvement process at an early stage.
Giovanni (1983)	Discusses RSM and product optimization together with sensory evaluation.
Henika (1982)	Use of response-surface methodology in sensory evaluation.
Henika (1972)	Simple and effective system for use with response surface methodology.
Henselman et al. (1974)	Use of response surface methodology in the development of acceptable high protein bread.
Korth (1982)	States "sensory evaluation strives to predict."
Lah et al. (1980)	A response surface methodology approach to the optimization of whipping qualities of an ultra-filtered soy product.

Table 2.1. Selected food-related literature utilizing response surface analysis (continued).

AUTHORS AND YEAR	TITLE OR EMPHASIS
Lane (1983), (p. 181)	Formulation variables affecting the flavor of extruded snacks and crackers, reporting the use of surface response methodology (SRM) for predicting the best combination of the various ingredients - "interactions among grain composition, internally and externally applied flavors in an extruded snack and the effect of fat composition and flavor in a snack cracker."
Li-Chan et al. (1984)	Hydrophobicity and solubility of meat proteins and their relationship to emulsifying properties.
Martin and Tsen (1981)	Baking high-ratio white layer cakes with microwave energy.
Nielsen et al. (1973)	Four factor response surface experimental design for evaluating the role of processing variables upon protein denaturation in heated whey systems.
Pearson et al. (1962)	Application of surface-response methodology to predicting optimum levels of salt and sugar in cured ham.
Sefa-Dedeh and Stanley (1979)	Cowpea proteins. 1. Use of response surface methodology in predicting cowpea (Vigna unguiculata) protein extractability.
Smith et al. (1977)	Physical stability of milk fat emulsions after processing as evaluated by response surface methodology.
Sullivan et al. (1981)	Carrot dehydration - optimization process studies on the explosion-puffing process.
Townsend and Nakai (1983)	Relationships between hydrophobicity and foaming characteristics of food proteins.
Voutsinas et al. (1983)	Relationships of hydrophobicity to emulsifying properties of heat denatured proteins.

Table 2.2. Selected, annotated references actually reporting use of existing computer programs which mention RSM calculations and response surface analysis plotting/graphics methods.

Programs/Methods Used for RSM Calculations	Authors
Hewlett-Packard Model 9820A calculator and Hewlett-Packard 9862 plotter, equations from text by Davies (1954).	Aguilera and Kosikowski, 1976
Hewlett-Packard flatbed plotter, surfaces.	Elgedaily, et al., 1982
Texts (3-D) by Earle, 1973; Newman, 1979, Rodgers and Adams, 1976, programs cited, e.g., CONSUR, DRWBAR, DISSUR, SAXES. See references. Alphanumeric labelling, shaded 2-D polygon capability in Applicon Color Plotting System library.	Bishop, et al., 1981
APL system for contours - Gilman and Rose ref., 1970.	Deng and Tomaszewski, 1979
Harrison's reference = Barr, et al., 1979, SAS Users Guide (1983) and Holt also refers to a SAS Guide, no date given. Box (1952) in Holt et al., 1984.	Harrison, et al., 1983; Henselman, et al., 1974; Holt et al., 1984; Lane, 1983
Interactive computer program, world-wide use, through General Electric Timesharing, Network Software Services, Rockville, MD - mini map optimization routine, contour maps, levels = letters of alphabet. References to Henika 1978 and 1976.	Henika, 1982
Reference to Sampson, 1975.	Johnson and Zabik 1981
Monroe 1880 programmable calculator, using algorithm (Cochran and Cox, 1957) UBC Triangular Regression Package, plots and surfaces by UBC Surface Visualization Routines program for Amdahl 470 V/8 computer, tiltable views. Nakai, 1982 gives numerous super-simplex references.	Li-Chan et al., 1984; Nakai, 1982; Townsend and Nakai, 1983; Voutsinas, et al., 1983

Table 2.2. Selected, annotated references actually reporting use of existing computer programs which mention RSM calculations and response surface analysis plotting/graphics methods.

Programs/Methods Used for RSM Calculations	Authors
Text, Myers, 1976; GLM and MATRIX procedures of SAS Statistical package, (Helwig and Council, 1979) and GCONTOUR of the SAS/GRAPH plotting package, (Council and Helwig, 1981) on a Tektronix 4662 plotter.	Roush, 1982
Oregon State University, SIPS (Statistical Interactive Programming System), OSCAR (Oregon State Conversational Aid to Research) systems, plotting on Hewlett-Packard 9825A calculator and 9862A plotter.	Roush, et al., 1979
UCDRSM, EBCDIC, Fortran, Tektronix 4010, Calcomp plotter, useful Appendix in paper.	Smith, et al., 1977
Myers, 1971; nonlinear programming routine, Cohen and Stein, 1976; McLean and Anderson, 1966, for simplex-centroid, Snee, 1975, and Cornell and Ott, 1975	Soo, et al., 1978
Evans, 1975, text on OPTIM program	Sullivan, et al., 1981
Perspective views (simplex-centroid) polynomials; TMRASW "User's Guide" for scientific subprogram library, 1978; Yanase, 1978, perspective views (Japan) TPERSP-program library	Toyomizu et al., 1982

SURCON PROGRAM DESCRIPTION

Interactive Sequence

SURCON is a user-friendly interactive program. In this paper, reference will be made to SURCON and a utility program, SURCONN. Basically, the SURCON program evaluates a response surface and draws a SURface and CONtour plot, hence the name SURCON. The program SURCON was written in FORTRAN (1977 standard) for a CYBER 170/720. It uses an independent, locally-written set of plot drivers called CYBER COMPLOT. Figure 2.1 presents a condensed version of the general flow chart of the SURCON program.

Assumptions

Figure 2.1 indicates the function options available; however, for the illustrations in this paper, the quadratic function will be the focus. This program evaluates an equation containing two (independent) variables to form a matrix of numbers which are first displayed as a two-dimensional (2-D) contour plot (Fig. 2.2A-2.2B) and then displayed as three-dimensional (3-D) response surfaces (Fig. 2.3A-2.3H) as viewed from one or more locations (viewpoints). The matrix built by SURCON has X values increasing from left to right and Y values increasing from bottom to top. This is clearly shown in the contour plot layout (Fig. 2.2A and 2.2B). The height of the response surface is represented mathematically by the Z-axis (Fig. 2.3).

The program was developed to visually show the results of

Fig. 2.1. Steps for using the SURCON Surface-Contour Plotting Package (* denotes noteworthy features).

PRELIMINARY STEPS
1. Data preparation and assumptions
2. Log on to CDC CYBER 170/720
3. TITLE line printer LOG file
4. TITLE Zeta plot fit
5. BEGIN SURCON procedure

BASIC OUTPUT CONTROL SPECIFICATIONS
1. Choice of plotter
2. Model numbers, Baud rate
*3. Width and height of Zeta plot
*4. Contour/Surface Label

X-AXIS, Y-AXIS, FUNCTION SPECIFICATION
1. X minimum, maximum
2. X axis increment/interval size
3. Y minimum, maximum
4. Y axis increment/interval size
*5. Choice of functions**
6. Coefficients on file (Y/N)
7. File name or enter coefficients

Fig. 2.1. Steps for using the SURCON Surface-Contour Plotting Package (* denotes noteworthy features) (continued).

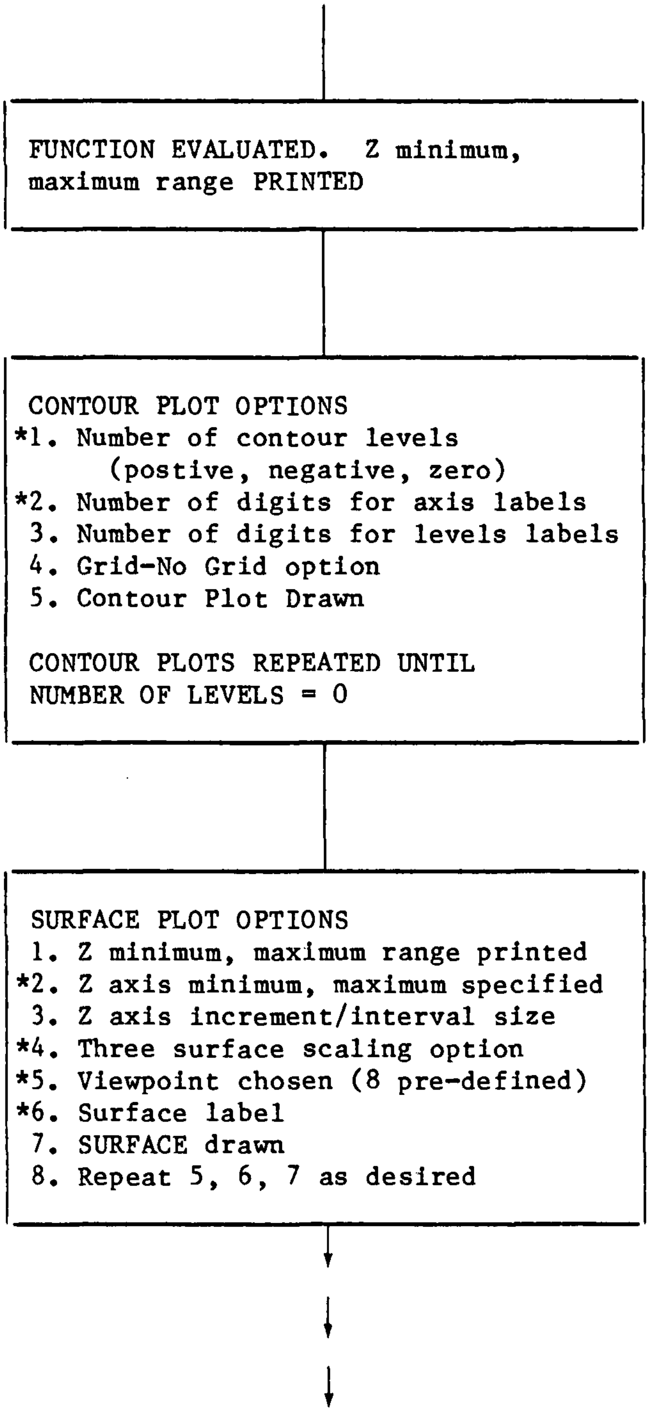
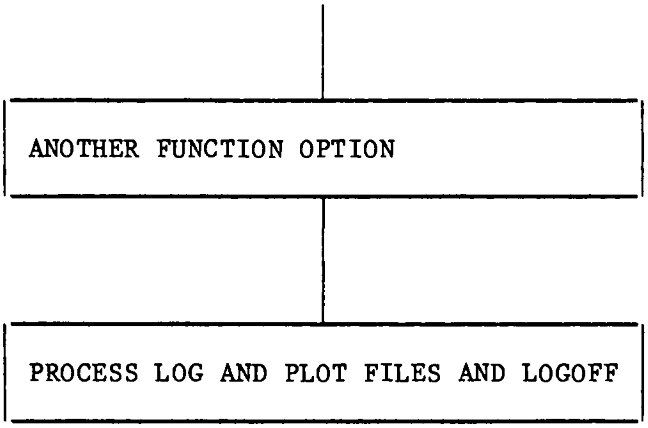


Fig. 2.1. Steps for using the SURCON Surface-Contour Plotting Package (* denotes noteworthy features) (continued).



**CURRENT FUNCTIONS AVAILABLE:

Presently, there are five functions to choose from:

COBB-DOUGLAS $$Z = a + bX^{c} * Y^{d} \tag{2}$$

QUADRATIC $$Z = a + bX + cY + dX^{2} + eY^{2} + fXY \tag{3}$$

C.E.S. $$Z = a + (bX^{c} + dY^{c})^{1/c} \tag{4}$$

CUBIC $$Z = A + bX + cY + dX^{2} + eY^{2} + fX^{3} + gY^{3} \tag{5}$$

GENERIC $$Z = \mathop{\mathrm{Sum}}_{i=1}^{N} (a_{i}X^{bi}Y^{ci}) \tag{6}$$

applying the significant variables of a two-factor central composite rotatable design of various dependent, (Y-) or response variables predicting meat quality to response surface analysis. The two factors or independent (X-) variables chosen were cooking temperature (CT) and endpoint temperature (ET). For clarification, it should be noted that reference is being made to the two "X" or independent variables, which are referred to as CT (^{o}F) and ET (^{o}C), as is seen from the quadratic regression Equation 1:

$$\hat{y} = A + B*CT + C*ET + D*CT*CT + E*ET*ET + F*CT*ET \quad (1)$$

where A through F are partial regression coefficients for the predictive model, the asterisk represents a multiplication sign, and $\hat{y}$ the predicted response value.

The description of the quadratic regression function here is:

X = 1st X-variable, contour plot, horizontal axis, CT;
Y = 2nd X-variable, contour plot, vertical axis, ET; and
Z = Response variable, $\hat{y}$, flat contour lines on contour plot, and Z-axis or height and nature of 3-D surface.

Strictly speaking, the independent variables could be termed X_1 and X_2, respectively, but for the purpose of this paper, X_1 will be placed on the traditional, horizontal X-axis and X_2 on the traditional, vertical Y-axis. The $\hat{y}$ response will be referred to as being on the third dimensional Z axis. The terms "dependent variable" and "response" are used interchangeably.

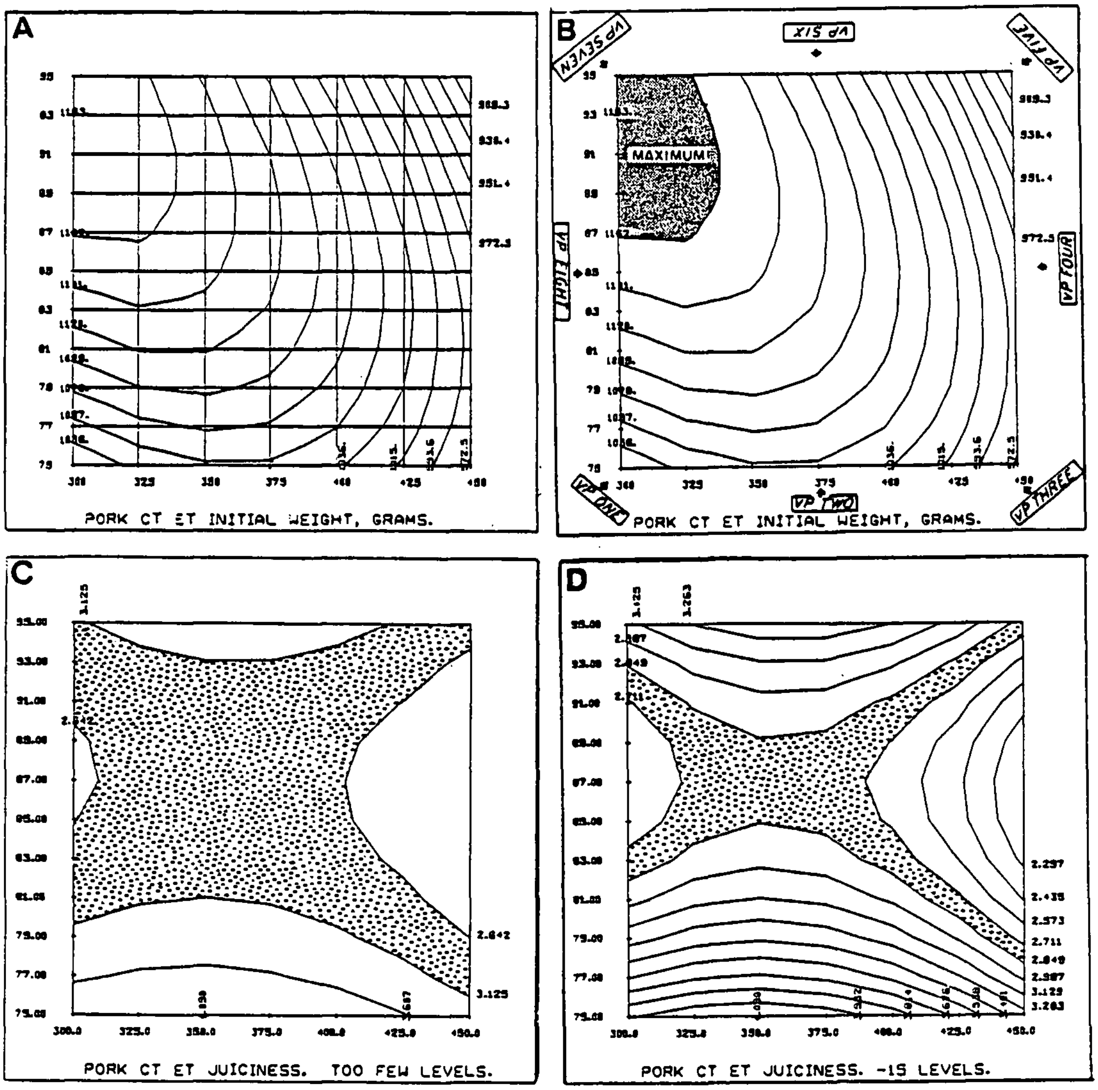


Fig. 2.2. Examples of various contour plots showing SURCONN features: grid versus no-grid option (A-B), number of contour lines (C=too few; D=informative). Note: Default viewpoints (VP) 1-8 also indicated on B.

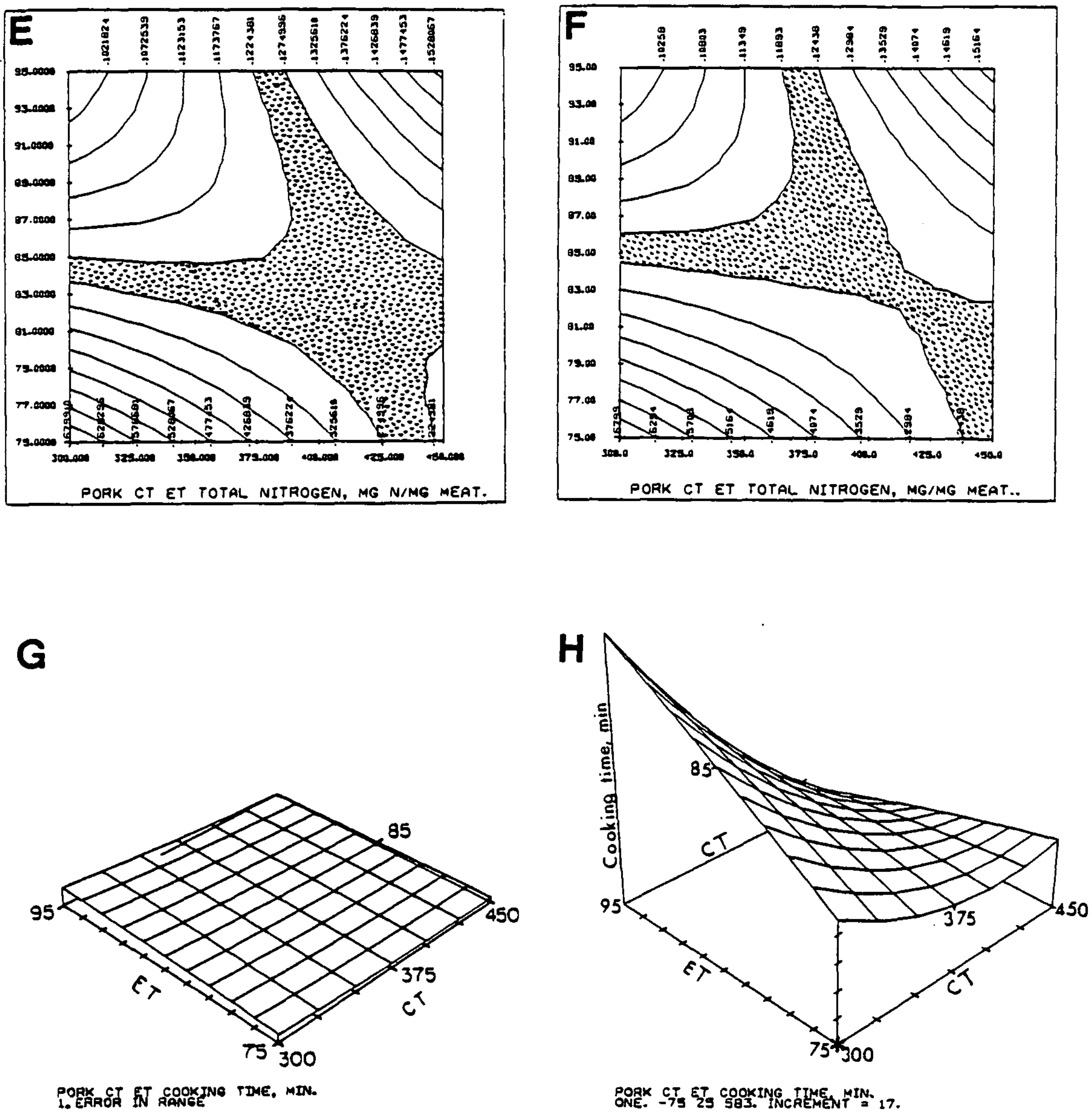


Fig. 2.2. Examples of various contour plots showing SURCONN features: number of digits for contour levels (E=too many; F= improvement), effects of Z-range on scaling (G=incorrect range; H=automatic).

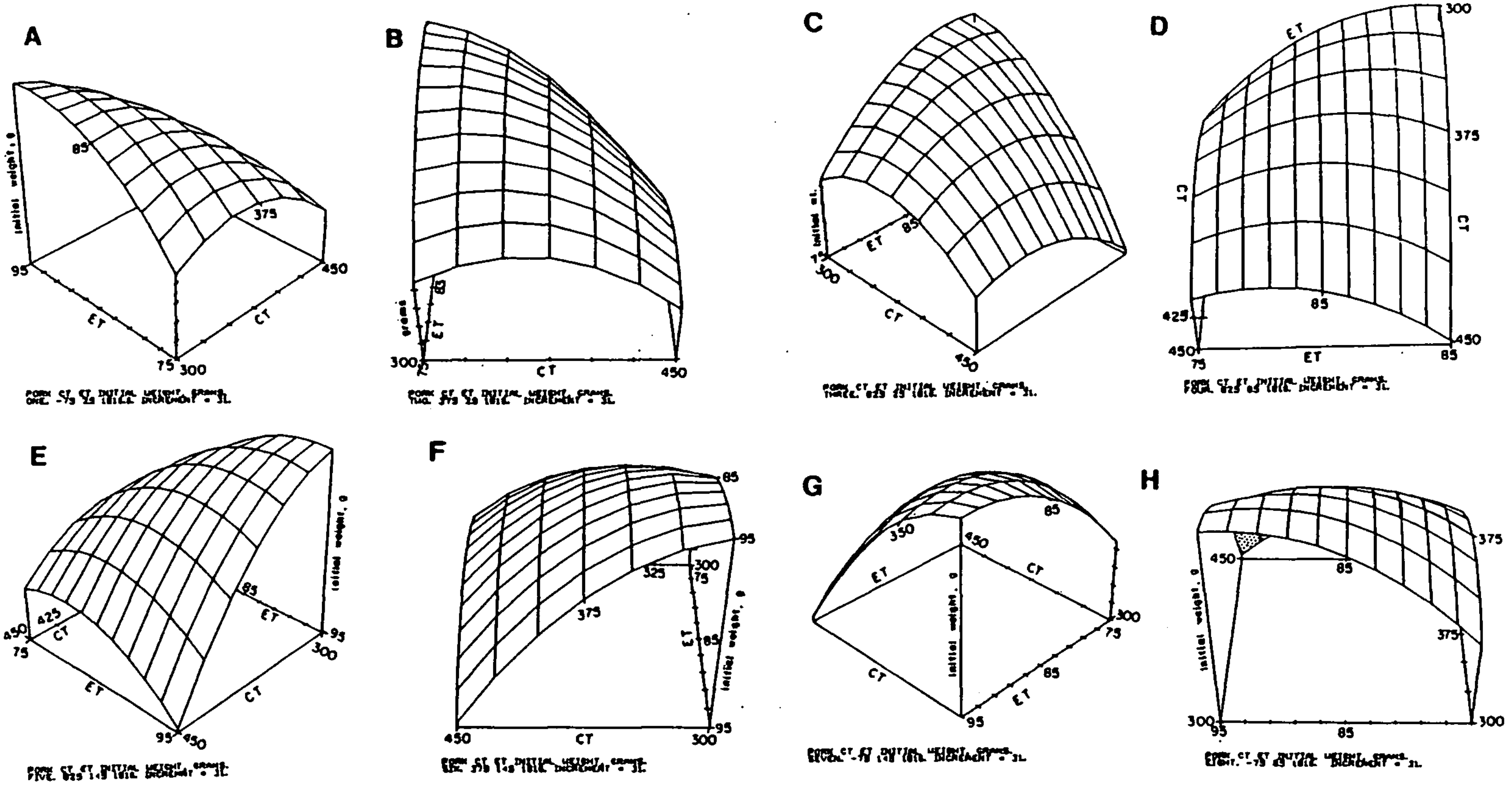


Fig. 2.3. Pork initial weight response surfaces showing all eight viewpoints (A-H). Z-axis represents height of surface.

Special Noteworthy Features

Explanations are done with the aid of a contour plot (Fig. 2.2) and a response surface (Fig. 2.3A-2.3H), as this makes it more visual. Following is a brief description of the capabilities included in this program to maximize interpretation of the contour plots and response surfaces. In programs developed by other users, inclusion of these capabilities would enhance effectiveness.

Contour plots

*Plot size. The ZETA plotter's plots can be made of varying widths and heights up to a maximum of 30 inches (75 cm) square.

*Initial label. SURCON allows for a label up to 40 characters (including spaces) for the 2-D contour plot (usually referred to as the contour plot) and 3-D response surface (usually referred to as the response surface). This is essential when one is doing numerous plots, as it helps to furnish immediate identification at a glance. The contour plots only have one label, whereas provision is made for the response surfaces to have two - one below the other (Fig. 2.3A-2.3H).

*Number of contour levels. In the 2-dimensional contour plots, the height of the surface (third dimension) is represented by the use of contour lines of different values, like topographical maps. The user may choose the number of contour levels desired up to 20. A positive number entered will mean that the user has to choose and enter the required contour level values. A negative value for the desired number of levels means that the program will calculate the contour level values spaced equally between the minimum and maximum.

This is useful in studying data or for publication, especially if there is a hard copy device connected to the graphics terminal, as one can then quickly make a copy, evaluate it and decide on the most meaningful values to be entered later and then drawn in by the computer. For example, it is less crowded on the plot to use exact numbers, rather than numerous decimals (Fig. 2.2C-2.2D). Five or 6 levels are sometimes recommended for initial exploratory work, although this might not prove informative enough (Fig. 2.2E), and 14 to 20 (maximum possible) for when one wishes to study a particular area of the surface more closely (Fig. 2.2F). One might also wish to restart the program and "zero in" on a particular area. This may be done by choosing narrower regions of CT and ET and one's own contour levels. Too many contour levels can result in an over-crowded appearance that is not always easy to follow or interpret.

*With or without grids. Following on from the number of contour levels, the program now allows for the matrix grid lines to be suppressed or left in. The program also allows one the option of one plot with a grid and another immediately following without a grid, without having to go through the surfaces to the end of the program (Fig. 2.2A-3.2B). The program allows one to loop back to choose other contour levels, labeling digits and a grid or no grid. One may also skip the contour plot altogether by specifying zero contour levels. For repetitive, developmental work this is very time-saving, even though it means responding to another interactive question. One can also enter a carriage return to end the response surface part quickly, in order to graph another function.

* Control over contour plot and contour level digit labels. Before drawing the plot, the final information required is the number of digits required to label both the X and Y contour plot axes and a separate number for the contour levels themselves. In this case a negative number allows for whole numbers to be used. One must remember to include spaces for decimal points and the plus or minus signs, even if not literally present, such as the plus sign that is understood in front of a positive number. Five or six digits are customary, for example, 1000 is "-5" and -375.0 is 6 digits whereas 50.0 is 5. An excessive number of digits results in a cluttered appearance (Fig. 2.2C versus 2.2D), although it is sometimes necessary to use six decimal places in order to obtain informative labels and levels (for example, if all the levels begin with "0.002", a fourth decimal place is needed).

Response surfaces

After the contour plots are completed, the program reminds one of the Z minimum, maximum and range values again, so that one can round up the maximum number and round down the minimum. At this stage it does not alter the basic function or matrix of Z values. A carriage return ends the surface part of the program. When the chosen range is close to the actual range, the resulting display will be more pronounced than if the chosen range is much greater than the actual range as this tends to flatten out the display. This could distort the response surface (Fig. 2.2D versus 2.2H).

*Height or three dimensional. The Z-axis actually forms the "height" (third dimension) of the response surface and, in fact, consists of 4 "legs" - one each on each corner of the four X-Y junctions. This Z-range refers to the highest or tallest area of the 3-D response surface. Again, the program asks whether one wishes to specify either the increment size or the number of intervals. This information is to decide where to put the tick marks on the Z-axis that is found at the junction of the minimum X and minimum Y axes. If the increment size cannot be divided into the Z-axis evenly, it is adjusted so that it is divisible and then it prints the updated Z-minimum, Z-maximum, increment and number of divisions.

*Surface scaling options. Often the respective ranges of the X, Y and Z-axes are quite different in magnitude. This presents a problem when drawing the representative surface. The best visual presentation occurs when the three ranges are about equal, although this might be construed to distort the response. If all are viewed under the same basic range-ratios, then this would serve to cancel the scaling-adjustment to the data.

There are three surface scaling options to choose from:

1. UNIFORM scaling option - where 1 unit of X = 1 unit Y = 1 unit Z;
2. AUTOMATIC - where range X = range Y = range Z (default option);
3. USER DEFINED - where the user specifies the X and Y scaling factors, using range Z as a standard.

UNIFORM scaling option amounts to no scaling at all as it is only suitable when the ranges are close.

AUTOMATIC scaling option provides the best opportunity of getting a reliable viewable surface. However, the viewer needs to be aware that since the three axes appear equal even though they are not, it might also result in some confusion. An example is where the X-axis range is 150°F, the Y-axis range is 30°C. This scaling option would make this rectangle appear as a square.

USER DEFINED scaling option is the program used under the name SURCONX - where the user specifies the X- and Y-scaling in terms of the range of the Z-axis. If one picked this option and specified 1 and 1, then one would have the same result as AUTOMATIC scaling.

*Viewpoints. There are eight possible standard viewpoints as indicated on Fig. 2.2B. One chooses from 1 to 8 (as many as desired) or one chooses "zero" if one wishes to define one's own viewpoint by specifying an X, Y, and Z coordinate. An example of such a set is shown in Fig. 2.3A-2.3H, using pork loin roast initial weight (g) as an example.

In Fig. 2.3A-2.3H, the eight viewpoints for the initial weight of the pork loin roasts show how the views vary, as one "travels around" the region studied and being evaluated. By cycling through the eight viewpoints one can see the surface from all sides. There is, of course, the corresponding cost of doing eight displays, but this feature enables one to view the more obscure areas or corners, so as to fully evaluate the effect of the CT-ET combinations in the case of the predictive meat work. However, in the case of the above-mentioned initial weight surfaces, this is not true, as the loin roasts were randomly allocated to the CT-ET combination and it is invalid to conclude that it is as a result of the temperatures.

The eight standard viewpoints are located in a plane that is twice the range of Z above the maximum Z value. The odd-numbered standard viewpoints are on the corners (2.5 times the range of X away from the minimum or maximum and 2.5 times the range of Y away from the minimum or maximum). The even-numbered ones are located midway between the respective corners (Fig. 2.2B).

*Labels. This is the label that is written underneath the label originally written for the contour plot (Fig. 2.3A-2.3H). Whether one defines one's own viewpoint or uses a standard one, the program will print the X, Y and Z-points used in the surface and then ask for a view label, also only 40 characters long. The label is useful, as one can write which viewpoint one chose, together with informative details one might wish to remember, for example, interval size. One could also simply press carriage return for no label.

This labeling feature is a great improvement on earlier versions of the program, as previously one had to choose values thought to give the best viewpoint(s). It was not predictable. Also, the fact that the minimum-maximum X- and Y-axes and the adjoining Z-axis have evenly-spaced perpendicular tick marks along them (asterisk, Fig. 2.3A), makes it possible to be confident where one is on the surface, i.e. where the lower or higher X and Y extremities are (Fig. 2.3A-2.3H).

*Screen plotting method. If this is done on a Tektronix terminal, the screen flashes and the surface will be drawn. This program draws the 3-D surface by first drawing the lines in the horizontal X-direction, followed by those in the Y-direction. As it draws the surface, hidden lines are removed and only those portions visible from the viewpoint are drawn. The surface is most-commonly viewed from above, yet, at times, the underside may be seen (dotted,

Fig. 2.3G-2.3H). After the surface is drawn, a base is drawn under it. This base represents the Z-minimum with vertical legs up to the upper four corners of the surface. Tick marks are drawn along the X, Y and Z axes which emanate from the coordinate of X-mimimum, Y-minimum and Z-minimum. This feature is extremely useful as it indicates where the minimum and maximum values are for the X and Y axes, and thereby makes possible more precise discussion of the nature of the response surface. This is probably the most significant improvement of this version of the program.

*Utility default version, SURCONN. This last feature allows the elimination of much of the repetitive interactive work as it can be written into a special version of the program. SURCONN has default minimum and maximum X and Y values associated with meat species 1-6 used in this experimental study. These are now supplied automatically by the program, whereas for SURCON, they have to be furnished repetitively and interactively. In Fig. 2.2A and 2.2B, the default for pork, species 6, is 300 - 450°F for the X-axis and CTs, and 75 - 95°C for the Y-axis and ETs. For the species studied here, the CT was kept constant throughout the experiment for comparative purposes across species at the end of the project.

Future Prospects

A number of changes in this evolving program are projected to help make it more "user friendly" and convenient.

1. Labels added to the axes of the response surfaces would enhance readability. By adding in the numbers corresponding to the tick marks, in a uniform manner, perpendicular to the specific axis

concerned, or uniformly and horizontally across the page, even more time and money would be saved. This is especially valid when these plots and surfaces are to be used in communicating one's findings to others.

2. The basic program might also be expanded to include additional functions as users develop new requirements.

3. The capability of entering a pre-gridded matrix of numbers instead of a function to evaluate, together with a feature which would write a matrix (which has resulted from a function evaluation) to a file for further study would enhance the visual effectiveness of any program..

4. The "AXIS OR NO AXIS LABELS" and "LEVEL LABELS OR NO LEVEL LABELS," options will be added.

5. An option which draws the under side of a surface in a different color than the top side.

It must be pointed out that capabilities described in this computer program, SURCON, are extremely useful in response surface analysis and for a wide variety of other graphics requirements. This paper reports some of the features that could be included in a graphics program. Researchers should be more cognizant of referencing their graphics routines in papers or reports comprehensively, as it not always clear as to how they were done. Of 46 food-related references consulted, less than 25% gave any substantial program details (Table 2.2). This SURCON program should remedy this state of affairs, as it is descriptive and easy to learn and use.

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Chapter 3

THE ABILITY OF A TWO-FACTOR QUADRATIC CENTRAL COMPOSITE ROTATABLE DESIGN WITH RESPONSE SURFACE ANALYSIS TO PREDICT PORK AND LAMB MEAT QUALITY CHARACTERISTICS.[1]

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MEAT QUALITY

(submitted to Journal of Food Science)

ABSTRACT

THE ABILITY OF A TWO-FACTOR QUADRATIC COMPOSITE ROTATABLE DESIGN WITH RESPONSE SURFACE ANALYSIS TO PREDICT PORK AND LAMB MEAT QUALITY CHARACTERISTICS. I.B. ZONDAGH, Z.A. HOLMES, D. E. SCHRUMPF AND K. ROWE, Dept. of Foods and Nutrition and Dept. of Statistics, Oregon State University, Corvallis, OR 97331.

A two-factor quadratic central composite rotatable design and corresponding response surface analysis were applied to data from pork and lamb loin roasts, using cooking temperature and endpoint temperature as the two independent variables. For pork and lamb, the dependent variables heating rate, evaporation loss, cooking time, total nitrogen, total moisture, and chromaticity coordinate (z) were found to be significant. Additionally significant variables for pork were remaining protein fraction, and for lamb, total cooking losses, expressible moisture index, chromaticity coordinate (x), saturation index and sensory panel doneness and color. Thus, the central composite rotatable design was successful. Contour plots and response surfaces for each significant variable were useful in evaluating results.

INTRODUCTION

The relationship of pork and lamb quality characteristics to various temperature/heat treatments is important to the success of the meat industry. Literature reports indicate concern for products of optimum quality characteristics. However, much of the early research focused on the influence of cooking and endpoint temperatures on the various quality characteristics. For example, Mackey and Oliver (1954) evaluated pork loin sampling methods for cooking tests, and Tuomy and Lechnir (1964) reported the effect of cooking temperature and time on the tenderness of pork. Bowers and Goertz (1966) and Holmes et al. (1966) evaluated the effect of internal temperature on eating quality of broiled chops. In these studies, results found were unique to the specific experimental conditions under which the research was done.

The need to improve lamb palatability is also considered important (Lind et al., 1971) by the sheep industry. There is a renewed interest in lamb and mutton flavor components, because they are distinctive from those encountered in other meat species (Crouse, 1983, Cramer, 1983, and Field et al., 1983, Vesely, 1973). However, little has been written about cooking temperature effects on lamb.

The objectives of this study were to investigate the ability of a two-factor central composite rotatable design (CCRD), using cooking temperature (CT) and endpoint temperature (ET) as the independent variables, to predict selected chemical, physical and sensory pork and lamb loin quality characteristics considered important by the industry, researcher and consumer alike. Response surface analysis (RSA) was used simultaneously to evaluate the nature of the responses obtained with the 13 CT-ET combinations used on fresh pork and previously-frozen lamb loin roasts. Response surface methodology broadens the implications and deceases overhead costs in experimentation and product development (Henika, 1972). Response surface analysis (RSA) aids in the visualization of the predicting ability of the central composite rotatable design itself.

MATERIALS AND METHODS

Samples

Paired pork loins (averaging 1088 g, 22.7% total nitrogen, 74.2% total moisture) were obtained from 5.5 - 6 month old barrows and gilts that had been fed on 14% protein finishing diet. Paired lamb loins (averaging 424 g, 3.2% total nitrogen, 71.7% total moisture) from animals of unknown history were used. The animals were slaughtered at the Clark Meat Science Laboratory, Oregon State University. The pork and lamb carcasses were conventionally held for 48 hours at $0^{o}C$. Loin roasts were removed between the second and 10th vertebrae (thus including the third and ninth). Both left and right side cuts were individually wrapped in film-lined freezer wrap. Pork was stored at $3-4^{o}C$ for 3 to 7 days before roasting according to the experimental design and roasting was completed within 7 days. Lamb samples were stored at $-18^{o}C$ until testing. Roasts were defrosted 48 hours ($4^{o}C$) before roasting.

Statistical Design

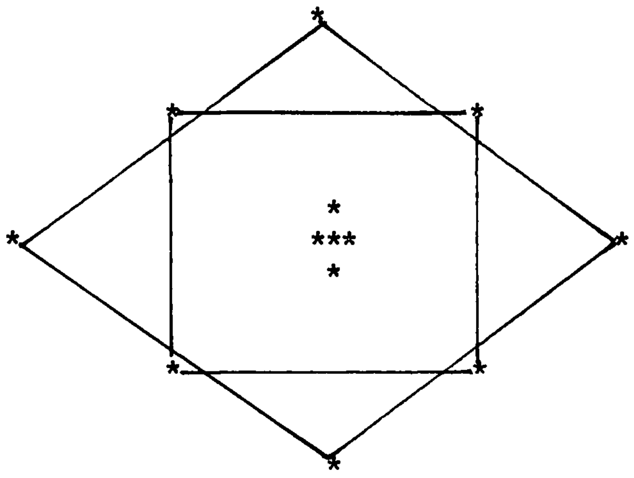
A two-factor Central Composite Rotatable Design (CCRD) was chosen to allow maximum cooking and internal endpoint temperature coverage with the limited amount of sample available (Cochran and Cox, 1957). The independent (X)-variables were the cooking (oven) temperatures (CT) and the internal endpoint temperatures (ET). The results obtained from the objective (chemical and physical) and sensory tests were regarded as the dependent (Y)-variables or responses. Table 3.1 depicts the basic pork and lamb CCRDs with the four factorial points, the four extra "star" and five center points (Cochran and Cox, 1957), with the added ^{o}F-^{o}C conversions where relevant. The CT range chosen for pork was 300^{o}F (149^{o}C) to 450^{o}F (232^{o}C) (customary household oven temperatures used), and the ET range was from 77 to 95^{o}C. The corresponding values calculated to represent the various design points (1.414, 1, 0, -1.414 and -1) are also given. The CT range chosen for lamb was also 300^{o}F (149^{o}C) to 450^{o}F (232^{o}C) and the ET range was from 60 to 90^{o}C, with 375^{o}F (191^{o}C) and 75^{o}C as the corresponding center point CT-ET combinations. The corresponding values calculated to represent these various points are also given.

For lamb, two replications of 13 CCRD points (total 26) paired lamb loins were roasted as the single loins were too small for simultaneous chemical, physical and sensory testing, and, statistically, duplicates of the design strengthen the results. Cooking losses and total cooking times were determined on both sets of 13 lamb roasts, resulting in a double set of information available for these Y-variables.

Table 3.1. Visual display of the pork and lamb loin cooking temperature-endpoint temperature combinations, used for this CCRD design with two independent variables. Cooking temperature is given in both °C and °F, with endpoint temperature only in °C.

Design Points	-1.414	-1	0	1	1
Cooking Temperature, °F	300	322	375	428	450
Cooking Temperature, °C	149	161	191	220	232

Design Points	Endpoint Temperature, °C Pork	Lamb
1.414	95.0	90.0
1	92.0	85.6
0	85.0	75.0
-1	78.0	64.4
-1.414	75.0	60.0



Sample Preparation

Each individual pork or lamb loin roast was placed on a wire rack in a foil-lined, aluminum roasting pan and baked in the center of a preheated, self-cleaning electric oven. CT-ET combinations were randomly allocated to the raw pork and lamb roasts, respectively. One CCRD design replication was done for pork, whereas two were done for the lamb loin roasts, using the left sides versus right sides and resulting in 26 observations. The roasted, excised longissimus dorsi muscle was used for the various physical and chemical tests (Fig. 3.1A and 3.1B).

Testing Methods

Cooking loss and cooking time were determined on each pork and lamb roast. Tenderness, total nitrogen, protein solubility, total moisture, expressible moisture index, and color were evaluated on the excised longissimus dorsi muscle (Fig. 3.1). Baseline data for these tests were also obtained on three raw pork samples and one lamb loin.

The left pork and lamb loin roasts were used for evaluating the following response variables: total nitrogen, protein solubility, total moisture, and expressible moisture index and the right loin roasts for sensory, Photovolt color and Warner-Bratzler (W-B) shear tests (Fig. 3.1A). The pork sensory test sampling is indicated in Fig. 3.1A and the sampling strategy for lamb sensory and shear tests is shown in Fig. 3.1B.

Cooking data. The initial and final cooking weights of each loin roast were recorded. Total and drip cooking losses were calculated using initial and final total weight of each loin roast.

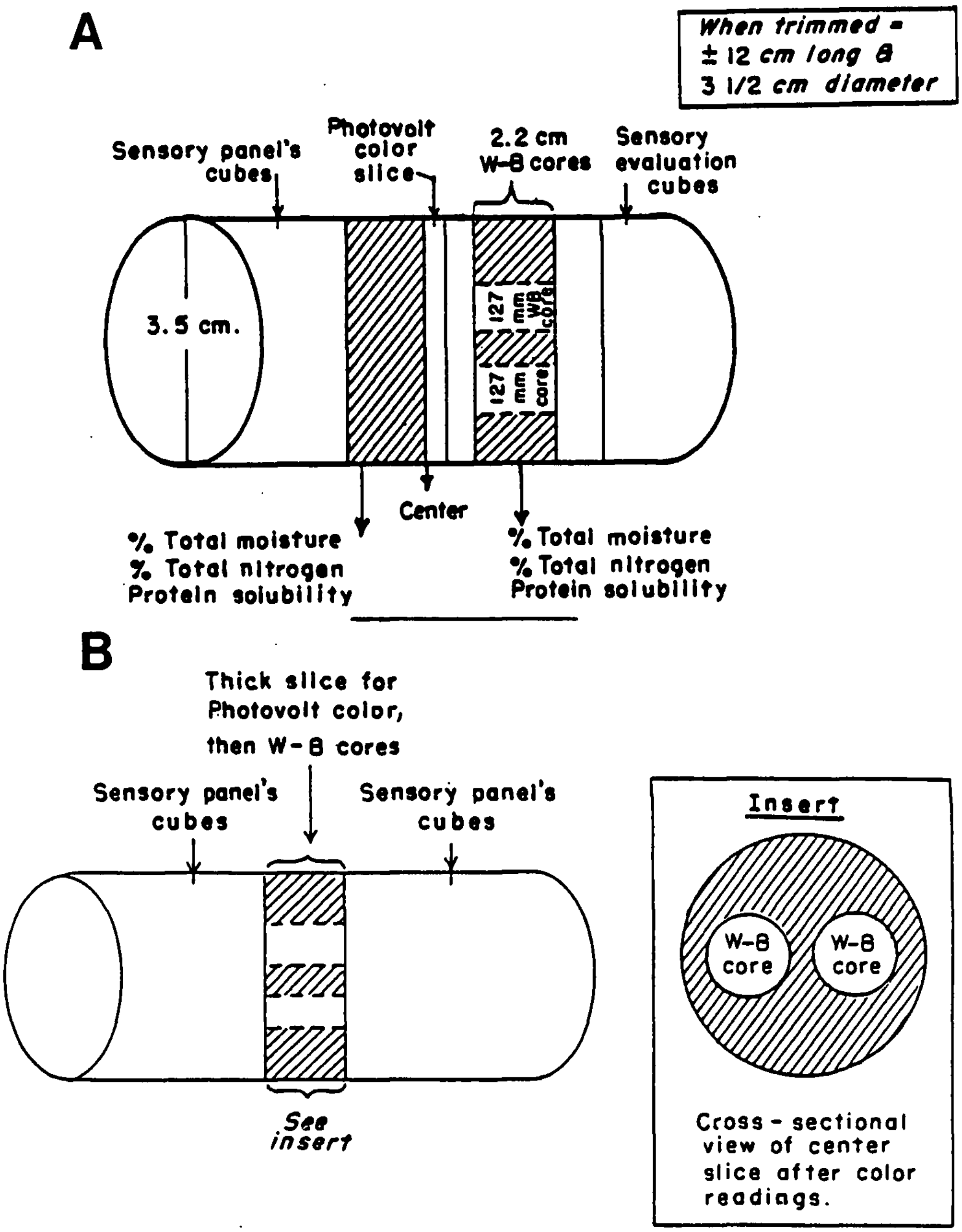


Fig. 3.1. Sampling diagram of excised longissimus dorsi muscles from pork and lamb loin roasts cooked according to CCRD-specified CT-ET combinations for chemical and sensory tests (A=pork; B=lamb).

Evaporation loss was calculated as the difference between the total cooking loss and the drip loss. Internal temperatures during the heating of the pork and lamb roasts were monitored at the center of the longissimus dorsi portion with a Leeds and Northrup W12 Temperature Recorder (Leeds and Northrup, Portland, OR), using a constantan-copper saber thermocouple. Heating rates were calculated as $^{o}C/g$, $^{o}C/min$, $^{o}C/g/min$.

Warner-Bratzler shear values. Tenderness was determined according to Riffero and Holmes (1983). Duplicate samples from each muscle portion were cut across the predominant longitudinal fiber direction (Fig. 3.1) using a 1.27 cm core meat sample on a Warner-Bratzler shear apparatus (25 kg x 50g dynamometer scale, G.R. Electric Mfg. Co., 1317 Collins Lane, Manhattan, KS).

Total moisture and water-holding capacity. Total moisture content was determined on duplicate 5 g cooked, chopped longissimus dorsi samples, according to the AOAC vacuum oven method (AOAC, 1980). The method of Wierbicki and Deatherage (1958) was used to determine the water-holding capacity. Triplicate sets of meat and juice areas of pressed muscle were measured with a Li-Cor LI-3100 Area Meter (Li-Cor, Inc./Li-Cor, Ltd., Lincoln, Nebraska 68504). The expressible moisture index (EMI) values were calculated as the ratio between the mean meat and mean juice areas.

Total nitrogen and protein extractions. Total nitrogen content was determined on duplicate samples (Fig. 3.1) of the finely chopped cooked and raw pork, according to the micro-Kjeldahl method (AOAC, 1980). The data were expressed as mg N/mg meat, wet and dry weight basis. The extraction method used for both low ionic strength

(LIS) soluble protein extract and non-protein nitrogen (NPN) extract/fraction was a modification of work reported by Hegarty et al. (1963), as only a 2 g sample was used and reagent volumes were adjusted to this weight.

Data collected were used for calculating percent total nitrogen, sarcoplasmic fraction (LIS - NPN), and remaining protein fraction (TN - (LIS + NPN)) which is thought to consist of the remaining fibrillar protein, high ionic strength soluble protein fraction(s), alkali-soluble protein and connective tissue residue (Hegarty et al., 1963).

Color measurement. The color differences of an inner slice (Fig. 3.1) of raw and cooked longissimus dorsi muscles were determined as percent reflectance (Photovolt Reflectance Meter, Photovolt, New York, NY 10010) with an enamel meat standard (amber, 21.0, blue, 25.0, and green 23.5). Duplicate amber (A), blue (B) and green (G) filter values were recorded and averaged. CIE chromaticity co-ordinates x, y and z as well as hue angles and saturation indices were calculated according to Gardner's Color scale conversion equations.

Sensory Tests

Eight and six Oregon State University staff members were selected through preliminary screening and trained to evaluate the 5 sensory characteristics for pork and lamb, respectively. They evaluated the tenderness (5=very tender, 1=very tough), flavor (5=very pronounced meaty flavor, 1=no meaty flavor), doneness (5=very overcooked, 1=very undercooked), and juiciness (5=very juicy, 1=very dry). Color descriptions were slightly different for the two species (5=greyish brown, 1=rosy pink for the cooked longissimus dorsi pork muscle and 5=brownish grey and 1=rosy red for the lamb).

In both cooked pork and lamb, four coded 150 mm cubes, each cut from the respective excised loin muscles (Fig. 3.1), were presented to each panelist. Color was evaluated on meat slices using light representative of daylight at high noon on a cloudy day (Executive Daylight Lamp BBx-324, Newbursh, New York 12550). The samples were evaluated at room temperature (21°C).

Statistical Data Analysis

The following quadratic polynomial regression equation (model) was used for evaluating the individual Y-variables:

$$\hat{y} = \text{Y-hat} = A + B*CT + C*ET + D*CT*CT + E*ET*ET + F*CT*ET \quad (1)$$

where, $\hat{y}$ = Y-hat = the predicted Y-variable's value,

CT = Independent variable, cooking temperature, °F, X1,

ET = Independent variable, endpoint temperature, °C, X2,

and A, B, C, D, E and F are the regression coefficients.

Computations were done on the CDC Cyber 170/720 computer (NOS 2.2 operating system) at the O.S.U. Milne Computer Center, Corvallis. The REGRESS subsystem of the Statistical Interactive Programming System (SIPS)(Rowe and Brenne, 1982) was used for regressions. The quadratic regression model, analysis of variance table (for regression and residual error sources), t-values, Y-hats, residuals and histograms of residuals were obtained. The sums of squares and variance values for each Y-variable were also calculated using SIPS. These values were used to calculate F-values and to test for lack of fit and the error term applicable. Significance was determined at the 10% level of probability for the Mean Square Regression/Mean Square Residual F-values, whereas the 20% level was used for initial screening for the Mean Square Lack of Fit/Mean Square Pure Error. For lamb, the same significance levels were used but the design replication resulted in the double regression procedure described below.

The F-value evaluation procedure for the double regressions is shown in Table 3.2 in sequential order. The paired left and right side loins (duplicates) were first compared to each other ("run") to ascertain whether or not they were similar, then the model (two independent variables) or "real/actual" regression (CT*ET), and, finally, the interaction of sides (run*regression), were checked, for the major source(s) of variation and for calculating the lack of fit and pure error components of the residuals sum of squares and mean squares. Histograms of the residuals were studied for outliers and these observations were then removed from the data sets before redoing the regressions and F-values.

Regression coefficients were used to create the Contour Plots and Response Surfaces, using plotting/graphics routines called "SURCONN" (Fuhrer, 1984). For each significant variable, a two-dimensional contour plot and three-dimensional response surface views were drawn/plotted and evaluated. Only the most informative ones are presented. This was always the contour plot without grid lines and response surface viewpoints one, three, five and/or seven.

Table 3.2. Double regression ANOVAs to illustrate F-ratio calculations.

Source of Regression	DF	Mean Square (MS) ratios for calculated F values	Ftable P-value and evaluation
Run (Left vs right side)	1	Run MS/Residual MS	0.10. If NS, sides do not differ.
Model or regression (CT*ET)	5	CT*ET MS/Residual MS	0.10. If NS, model or design is not suitable. Significance is desirable.
Run*Regression (Interaction of sides)	5	Run*Regression MS/ Residual MS	0.10. If significant, indicates trouble, as there is interaction of sides. The 2 sides regress differently.
Residual	14		
Lack of Fit	6	MSLF/MSPE	0.20. If N.S., use Residual MS as denominator for above F-calcs. If Significant, use LFMS as denominator above.
Pure Error	8	(evaluated first)	

The CT-ET variables are located along the traditional X and Y-axes of normal graph conventions while the response variable falls along the Z-axis which forms perpendicular "legs" and adds the third dimension to the flat surface or plane formed by the X-Y axes. The minimum CT-mimimum ET junction 300°F (149°C) and 75°C corner is marked with an asterisk to aid the reader in locating viewpoint one. Shaded areas indicate minimum or maximum regions or saddles. In the second line of the response surface label, the viewpoint used (1-8) is given first, followed by the CT and ET and values for the response variable that represent the viewpoint being used. This is followed by the interval size, should one wish to estimate the height above the base (Zondagh, 1984).

RESULTS AND DISCUSSION

Table 3.3 lists all the pork and lamb meat characteristics (Y-variables) with the P-values, if significant. For both species the heating rate (°C/min); evaporation cooking loss (%); total cooking time (min); total moisture (%); and chromaticity coordinate, z, differed significantly ($P \leq 0.10$). Within species, selected other dependent variables were shown to be significantly influenced by CT-ET combinations. For pork, the differences were total nitrogen (mg N/mg pork, dry weight basis), remaining protein fraction (mg N/mg pork, dry weight basis), and juiciness as scored by the sensory panel. Total cooking loss (%) was just slightly higher than the $P \leq 0.10$ limit set for the statistical evaluation of the data (0.11). For lamb, additional significant dependent variables from the double regression

Table 3.3. Within-species and across-species analysis of variance significant variables for fresh pork loin and frozen lamb loin for the two-factor central composite rotatable design (CCRD).

	P-values/Significance values	
Y-variables	Pork	Lamb
Initial weight, g (dummy variable)	N.S.[a]	N.S.
Heating rate, °C/g	N.S.[b]	0.08
Heating rate, °C/min,	0.01	0.07
Heating rate, °C/g/min	N.S.	N.S.
Total cooking loss, %	(0.108)[c]	<0.0001
Drip loss, %	N.S.	0.0002
Evaporation loss, %	0.08	<0.0001
Cooking time, min	0.04	0.0086
Expressible moisture index	N.S.	0.03
Percent total moisture	0.05	0.07
Warner-Bratzler, lb	N.S.	N.S.
Total nitrogen and %, wet weight	N.S.	0.01
Low ionic strength, wet weight	N.S.	N.S.
Non-protein nitrogen, wet weight	N.S.	N.S.
Sarcoplasmic protein fraction, wet weight	N.S.	N.S.
Remaining protein fraction, wet weight	N.S.	N.S.
Total nitrogen and %, dry weight	0.001	N.S.
Low ionic strength, dry weight	N.S.	N.S.
Non protein nitrogen, dry weight	N.S.	N.S.
Sarcoplasmic protein fraction, dry weight	N.S.	N.S.
Remaining protein fraction, dry weight	0.001	N.S.
Photovolt		
Amber filter	N.S.	N.S.
Blue filter	N.S.	N.S.
Green filter	N.S.	N.S.
C.I.E. values		
x	N.S.	N.S.
y	N.S.	N.S.
z	N.S.	N.S.

Table 3.3. Within-species and across-species analysis of variance significant variables for fresh pork loin and frozen lamb loin for the two-factor central composite rotatable design (CCRD).

	P-values/Significance values	
Y-variables	Pork	Lamb
Chromaticity coordinate, x	N.S.	0.007
Chromaticity coordinate, y	N.S.	N.S.
Chromaticity coordinate, z,	0.039	0.002
Hunter L-value	N.S.	N.S.
Hunter, a_L	N.S.	N.S.
Hunter bL value	N.S.	N.S.
Hue angle	N.S.	N.S.
Saturation index	N.S.	0.08
Tenderness	N.S.	N.S.
Flavor	N.S.	N.S.
Doneness	N.S.	0.006
Juiciness	(0.10)	N.S.
Color	N.S.	0.008

[a] N.S. means "Not Significant"

[b] Single regressions were done on the cooking loss data, cooking times and heating rates for pork versus double regressions on lamb.

[c] ( ) means "close to P=0.10"

analysis included the heating rate ($^{o}C/g$), cooking loss as total cooking loss (%), evaporation loss (%), and for the single regressions, expressible moisture index (EMI), total nitrogen (mg N/mg lamb, wet weight basis) and chromaticity coordinate x, saturation index, and sensory doneness and color.

Tables 3.4 and 3.5 lists all the significant, estimated Y-hat's partial regression coefficients for the quadratic model shown in Eq. 1 above for the pork and lamb. These may be used to predict response values for the significant Y-variables at other CT-ET (CT must be in ^{o}F and ET in ^{o}C) combinations that fall within the ranges of CT-ETs used in this study, by substituting the values for A-F in Eq. 1. This might be of special interest to the meat industry and/or institutions when wishing to predict cooking losses and cooking times.

Only eight of the 42 possible pork variables and 14 of the possible 42 lamb variables were significant at or below the $P \leq 0.10$ level. The identification of significance indicates that the quadratic regression model and the CCRD are suitable for these data and the corresponding response surfaces. The nature of the relationship between the independent and dependent variables is explained by the two-dimensional contour plots and the three-dimensional response surfaces. Judged overall from analysis not shown, there was no indication of variability amongst the pork cooking loss determinations and sensory evaluation (tenderness, flavor, doneness and color) and the protein solubility values; whereas there was a slightly greater variability among the Warner-Bratzler values and the most variability between the color data information. This type of analysis generally indicates a suitable design and laboratory

Table 3.4. Quadratic regression model coefficients for pork loin roast for substitution into Equation 1 (with cooking temperature in °F and endpoint temperature in °C).

	A (constant)	B	C	D	E	F
Heating rate, °C/min.	3.947	- 0.005929	- 0.07005	0.0000002778	0.0002142	0.0001029
Total cooking loss, %	- 357.3	1.248	3.025	- 0.0007928	0.0005741	- 0.007244
Evaporation loss, %	- 98.62	0.6686	- 0.6229	- 0.0007277	0.009413	- 0.00133
Cooking time, min.	- 907.9	0.8861	22.22	0.00308	- 0.02316	- 0.04542
Expressible moisture index	- 2.543	0.0008693	0.06163	0.000004881	- 0.0002219	- 0.00005717
Total moisture, %	494.2	- 0.847	- 6.111	0.00001626	0.01263	0.009756
Total nitrogen, mg N/mg meat dry wt. basis	209.1	- 0.3291	- 3.101	0.00005199	0.01006	0.003455
"Remaining" protein mg N/mg meat	1.795	- 0.002998	- 0.02605	0.0000003032	- 0.00007623	0.00003326
Chromaticity coordinate, z	- 0.4416	- 0.001109	0.02283	0.000001117	- 0.0001421	0.000003486
Juiciness sensory score means	63.89	0.04173	- 1.574	- 0.00007272	0.008807	0.0001148

Table 3.5. Quadratic regression model coefficients for lamb loin roast for substitution into Equation 1 (with cooking temperature in °F and endpoint temperature in °C).

	A (constant)	B	C	D	E	F
Heating rate, °C/g.	0.1288	- 0.0004988	0.001253	- 0.0000004943	- 0.00001464	0.00001036
Heating rate, °C/min	4.505	0.003527	- 0.1151	- 0.000003667	0.0006467	0.00003056
Total cooking loss, %	- 226.200	0.6142	2.674	- 0.0007551	- 0.01380	- 0.0001212
Drip loss, %	- 111.4	0.2705	1.474	- 0.0004472	- 0.01064	0.001103
Evaporation loss, %	- 114.8	0.3437	1.200	- 0.0003079	- 0.003164	- 0.0009819
Cooking time, min.	- 132.8	- 0.3468	6.593	0.0007212	- 0.02468	- 0.004709
Expressible moisture index	- 0.1256	0.0007076	0.002978	- 0.000004429	- 0.00009016	0.00003867
Total moisture, %	70.82	- 0.04453	0.3759	0.0001377	- 0.001952	- 0.0008225
Total nitrogen, mg N/mg meat wet wt. basis	0.05340	0.0005937	- 0.003621	- 0.000000699	0.00002838	- 0.00000083

Table 3.5. Quadratic regression model coefficients for lamb loin roast for substitution into Equation 1 (with cooking temperature in °F and endpoint temperature in °C) (continued).

	A (constant)	B	C	D	E	F
Chromaticity coordinate, x	1.400	- 0.002025	- 0.01644	0.000001964	0.00008504	0.000006507
Chromaticity coordinate, y	- 0.02915	0.0003852	0.007991	- 0.0000002762	- 0.00004595	- 0.000002447
Chromaticity coordinate, z	- 0.3815	0.001670	0.008613	- 0.000001733	- 0.00004028	- 0.000004055
Saturation index	175.0	- 0.2537	- 2.875	0.0001928	0.01444	0.001277
Doneness[1]	- 7.652	- 0.0006730	0.2437	- 0.00001815	- 0.00183	0.0001902
Color[2]	- 49.82	0.1272	0.6947	- 0.0001912	- 0.004928	0.000296

[1] Doneness: 1 = very undercooked; 5 = very overcooked

[2] Color: 1 = rosy pink; 5 = grey brown

technique.

Contour Plots and Response Surfaces

Heading rate, ^{o}C/min. The contour plot (Fig. 3.2A) for the heating rate (^{o}C/min) for pork loins shows contour level lines increasing in an almost linear fashion. This linearity is also evident in the 3-dimensional response surfaces presented from one viewpoint (Fig. 3.2B). As the CT-ET combination increases along the X-axis (cooking temperature), there is a trend toward a linear heating rate increase, whereas along the Y-axis (ET) there is almost no perceptible change except for a slight increase at the minimum CT-minimum ET and maximum CT-maximum ET junctions. Since cooking temperature is not a function in the quadratic formula for calculating this variable, this heating rate is shown to be a function of ET and not CT. These maximum and minimum values are possibly reflective of heat input, but also of protein denaturation and moisture evaporation (Cloke, et al., 1981).

Figure 3.2C is the contour plot for the heating rate for the cooked lamb roasts, expressed as ^{o}C/min. It is clearly evident that the lines are more curved (less linear) than those for the pork ^{o}C/min and lamb ^{o}C/g rates. The curvature as seen from viewpoint one reveals a decreasing rate from about 63^{o}C to 90^{o}C at lower CTs, but with CTs above 375^{o}F (191^{o}C) there is a rapid heating rate increase across all ETs. Between 75 and 79^{o}C ET there is a valley floor. This may relate to the endothermic protein denaturation reactions. The differences between the heating response surfaces in lamb and pork could be partially reflective of frozen versus fresh sample; however, of

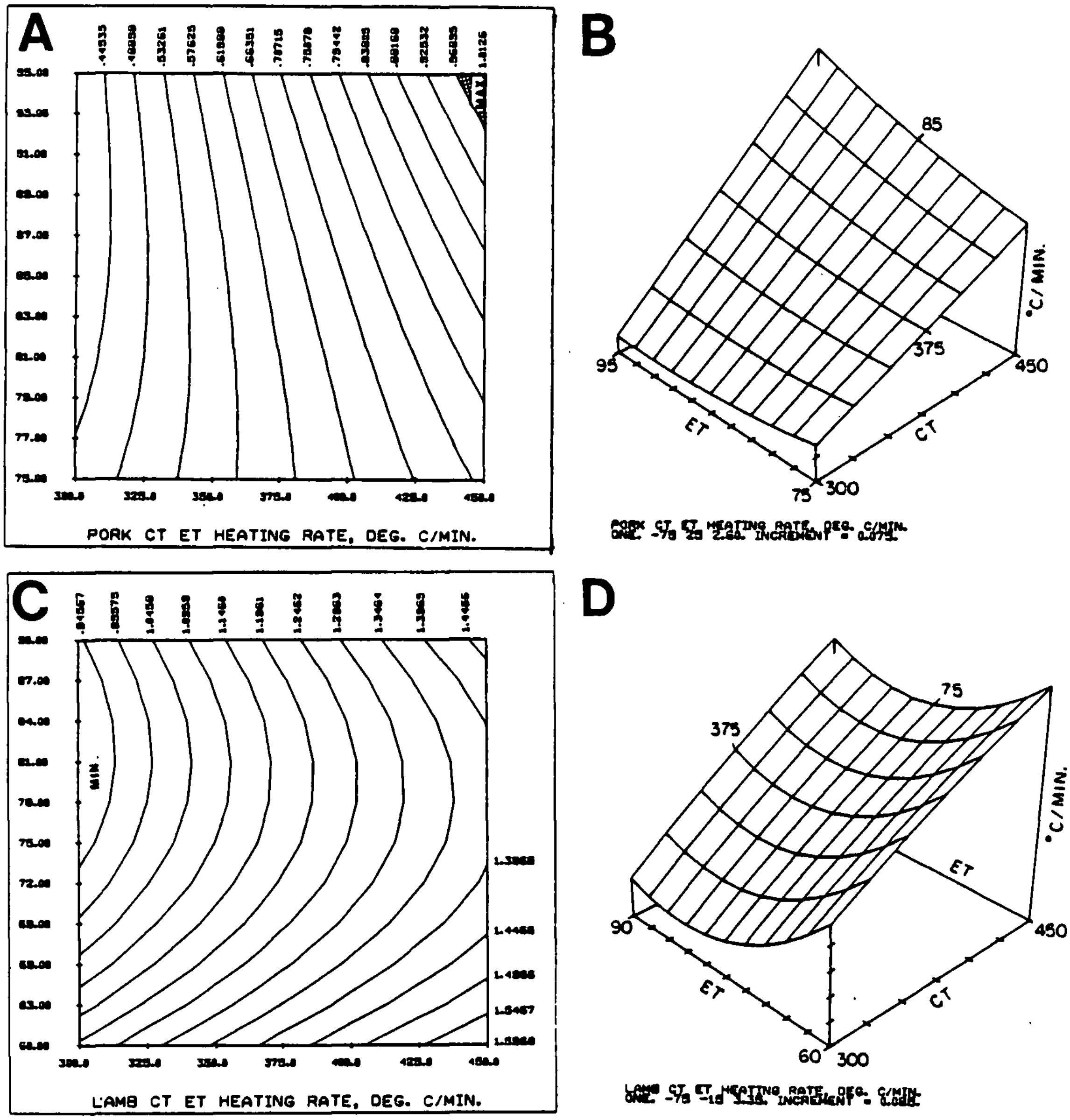


Fig. 3.2. Pork and lamb loin roast contour plots and response surfaces with independent variables of cooking (oven) temperature (CT, X-axis), °F, and endpoint temperature (ET, Y-axis), °C for the response variable (Z-axis), heating rate, °C/min for pork (A; B) and lamb (C; D).

greater importance could be sample size. Pork roasts were 40% heavier.

Lamb heating rate, $^{o}C/g$. Although this variable was not found to be significant for pork as well, it should be discussed together with the other heating rates. Figure 3.3A is the contour plot for lamb data calculated for the $^{o}C/g$ heating rate. The contour level lines appear to increase in an almost linear fashion from the X-axis (low ET) towards the higher ETs. Judging from the three-dimensional response surface shown in Fig. 3.3B, this heating rate is a linear relationship, with lower penetration rates at lower ET values, across the full range of CTs. The high CT-low ET corner has slightly lower values than the rest of that given ET area. More contour lines emanate from the ET axis, resulting in more change taking place in the heating rate ($^{o}C/g$) due to ET rather than CT. Moving vertically upwards on the contour plot (Fig. 3.3A), more contour lines are crossed than if one were to move along the horizontal axis. This underlines the fact that ET is more important than CT in this heating rate. This contour plot and response surface are very similar to that for cooking time (min) (Fig. 3.4D). In both lamb heating rates ($^{o}C/g$ and $^{o}C/min$), the contour plots are approaching maximum/ minimum areas (shaded, maximum for Fig. 3.3A and minimum for Fig. 3.3C).

Cooking Time. The computer-calculated cooking times for the range of ETs were 74.7 to 242.5 and from 36.7 to 94.3 minutes for pork and lamb respectively. From data shown in the pork contour plot (Fig. 3.4A) and the response surface (Fig. 3.4B), it will be noted that the longest cooking time (242.5 minutes) comes at the lowest CT 300^{o}F

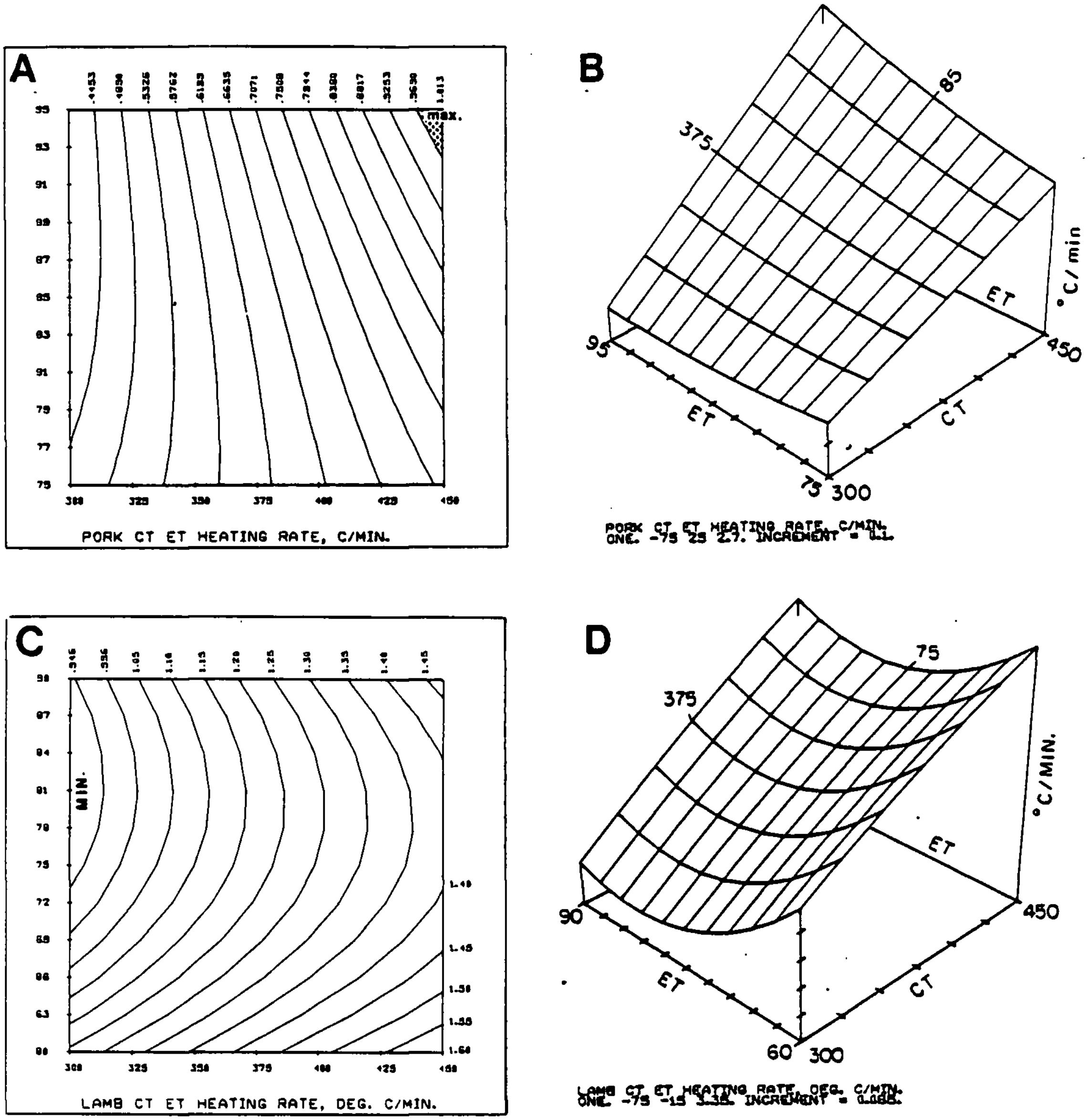


Fig. 3.3. Lamb loin roast contour plots and response surfaces with independent variables, cooking temperature (CT, °F, X-axis) and endpoint temperature (ET, °C, Y-axis), for the response variables (Z-axis), heating rate, °C/g (A; B) and expressible moisture index (EMI) (C; D).

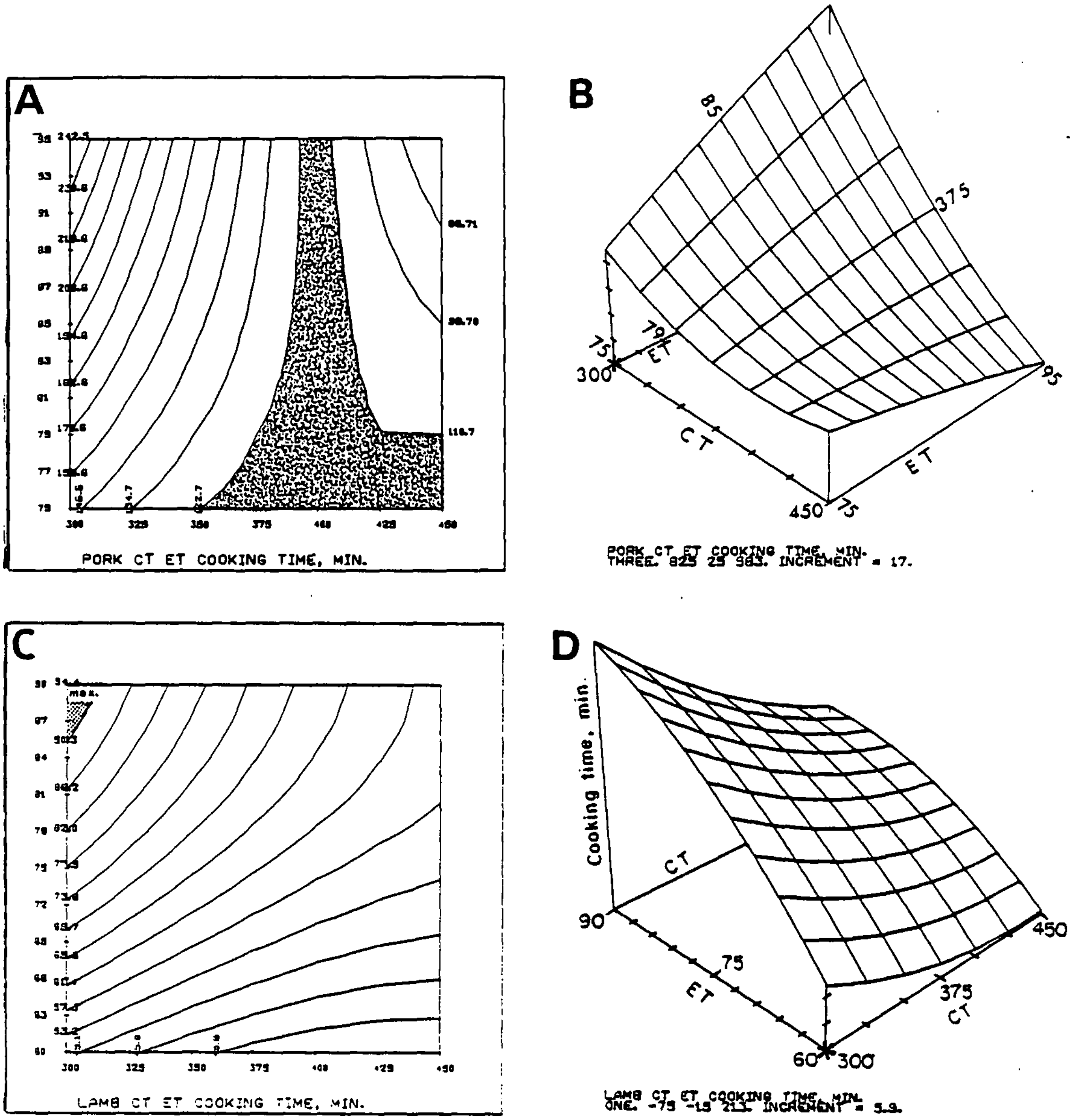


Fig. 3.4. Pork and lamb loin roast contour plots and response surfaces with independent variables of cooking temperature (CT, °F, X-axis), endpoint temperature (ET, °C, Y-axis), and for the response variable (Z-axis), total cooking time (min), for pork (A; B) and lamb (C; D).

(149°C)-highest ET (95°C) combination as would be expected (Brady and Penfield, 1982). If a CT below 405°F (207°C) is picked, and the contour levels are read from bottom to top, one notices an increase in cooking time (from about 135 to 160 min). The decrease when the CT is above 405°F (207°C) indicates that in predicting cooking time, there is not a linear relationship between time or cooking temperature when the latter value is high.

The lamb contour plot (Fig. 3.4C) and the response surface (Fig. 3.4D) both indicate that the longest cooking time also comes at the lowest CT 300°F (149°C) and highest ET (95°C) combination. The surface of the response surface is slightly curved and is not quite a linear plane. Judging from the contour plot, there is no maximum peak found in this variable. Part of the reason could be due to the fact that the roasts were not of exactly the same weight to begin with or the fact that the lamb had been frozen and thawed. Judging from the number and direction of contour lines, another factor to consider is that ET has more of an effect than does CT. There is a similarity in the shape of the °C/g (Fig. 3.3A) heating rate and cooking time plots and surfaces.

Cooking Losses. In analyzing pork and lamb data, evaporation loss (%) was the only common significant cooking loss variable. The pork contour plot (Fig. 3.5A) shows a ridge cresting at about 375°F (191°C), increasing steadily from minimum to maximum ET. A high degree of evaporation takes place between about 350 and 400°F (177 and 204°C), especially at the maximum endpoint temperature (ET) of 96°C. This is particularly clearly shown in the response surface (Fig. 3.5B). The amount of evaporation shown above 85°C is much higher

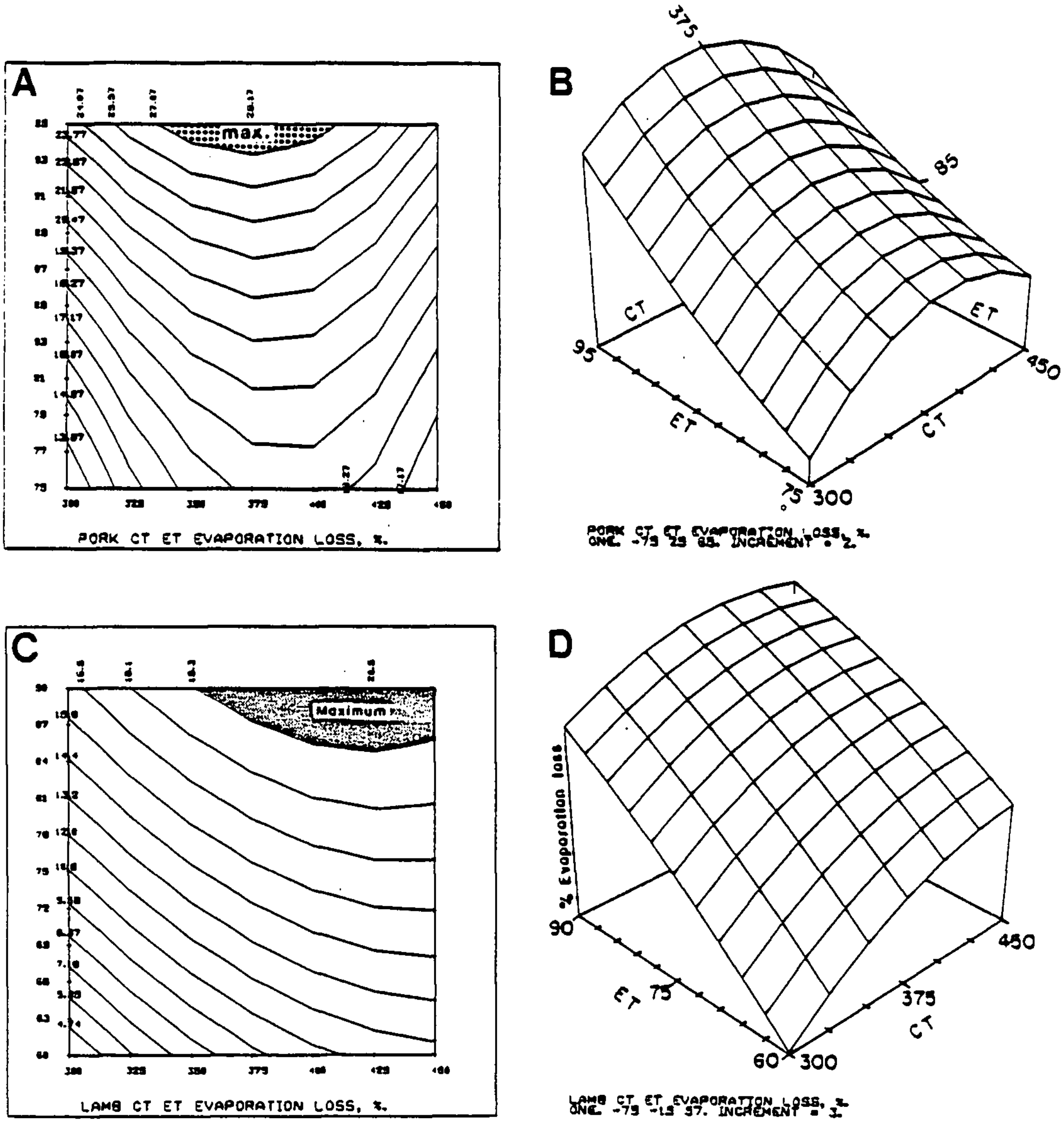


Fig. 3.5. Pork and lamb loin roast contour plots and response surfaces with independent variables, cooking temperature (CT, °F, X-axis) and endpoint temperature (ET, °C, Y-axis), for the response variables (Z-axis), pork evaporation loss (%)(A; B), lamb evaporation loss (%)(C; D).

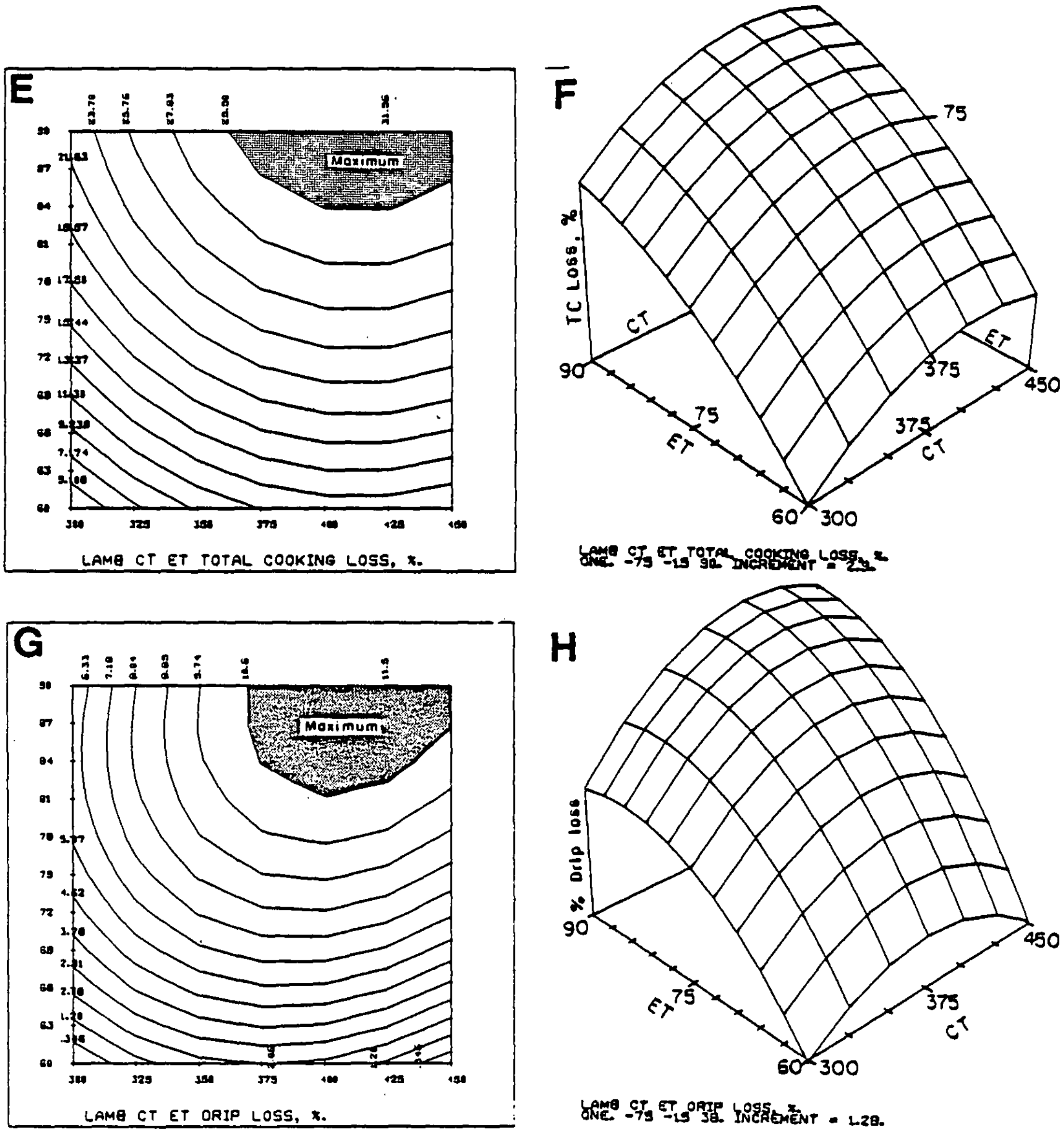


Fig. 3.5. Pork and lamb loin roast contour plots and response surfaces with independent variables, lamb total cooking loss (%)(E; F); and lamb drip loss (%)(G; H).

than at the min CT-min ET and max CT-max ET regions. A CT between 350 and 400^{o}F (177 and 204^{o}C) results in the highest amount of evaporation loss in pork loin roasts, and this loss increases from low (75^{o}C) to high (95^{o}C) endpoint temperatures.

For lamb, evaporation loss (%) plots (Fig. 3.5C and 3.5D) resemble the other two lamb cooking loss, total (Fig. 3.5E and 3.5F) and drip (Fig. 3.5G and 3.5H), in overall shape. As with the pork, the lamb contour plot (Fig. 3.5C) shows increasing evaporation loss (%) values from minimum to maximum ET. A high degree of evaporation takes place between about 375 and 450^{o}F (191 and 232^{o}C), and, as expected, this occurs mainly around the maximum endpoint temperatures (ETs) of 87-90^{o}C. Thus, the lower CT and ET ranges are preferable for reducing evaporation loss in lamb loin roasts.

Figures 3.5E-3.5F show the plots for total cooking loss for lamb loin roasts only, as the effects for pork roasts were not significant at $P \leq 0.10$. With the lamb roasts, nine contours (Fig. 3.5E) are crossed along the ET range from bottom to top (60 to 90^{o}C) as opposed to approximately five crossed when moving from low CT to high CT. Thus, although total cooking loss (%) is a function of CT, ET has more influence. The response surfaces show the highest cooking losses at the highest ETs, especially above 75^{o}C. As expected, maximum loss occurs at the maximum CT-maximum ET region. The highest loss (stationary point) is at 31.96% and this indicates that this combination of CT-ETs came close to the maximum value, as there is a definite hill present in the maximum CT- maximum ET "corner." Therefore, in roasting lamb, it would be best to avoid higher ET ranges (at any CT) in order to obtain better yields, especially

75°C ET and above.

Although not significant in pork, the significant lamb drip loss (%) contour plot (Fig. 3.5G) also indicates a high (11.45%) in the region of high CT-ET combinations. This drip is primarily fat and extractives (Lind et al., 1971). The surface (Fig. 3.5H) is decidedly curved, especially in comparison to total cooking (Fig. 3.5F) and evaporation (Fig. 3.5D) losses. The maximum ET-minimum CT area is lower in this case than the response surface of total cooking loss (%). The results visually shown in Fig. 3.5 are supported in work reported by a number of other researchers. Studies concerning the internal temperature of pork (Bowers and Goertz, 1966, and Webb et al., 1961) show that cooking loss increased as internal temperature of pork roasts increased. Brady and Penfield (1982) found that hot water bath and oven-roasted samples heated to 70°C lost more moisture than those heated to 60°C, and the samples heated at a faster rate lost less moisture than those at a slower rate.

All three of the cooking loss (%) measurements for lamb as plotted, show that the CT-ET combination is approaching a stationary maximum point within a maximum region (shaded areas, Fig. 3.5C, 3.5E and 3.5G).

Percent Total Moisture. Total moisture of the cooked meat is a related quality factor. The pork contour plot (Fig. 3.6A) shows a definite minimax-saddle arrangement, meaning that one of the X-variables (CT or ET) is at its maximum while the other is at its minimum. There is an "iso-moisture" content area (shaded area) between 60.69 and 61.78 %TM. This phenomenon occurs roughly between 85 and 87°C ET for low CTs and 83 and 86°C for higher ETs, and between

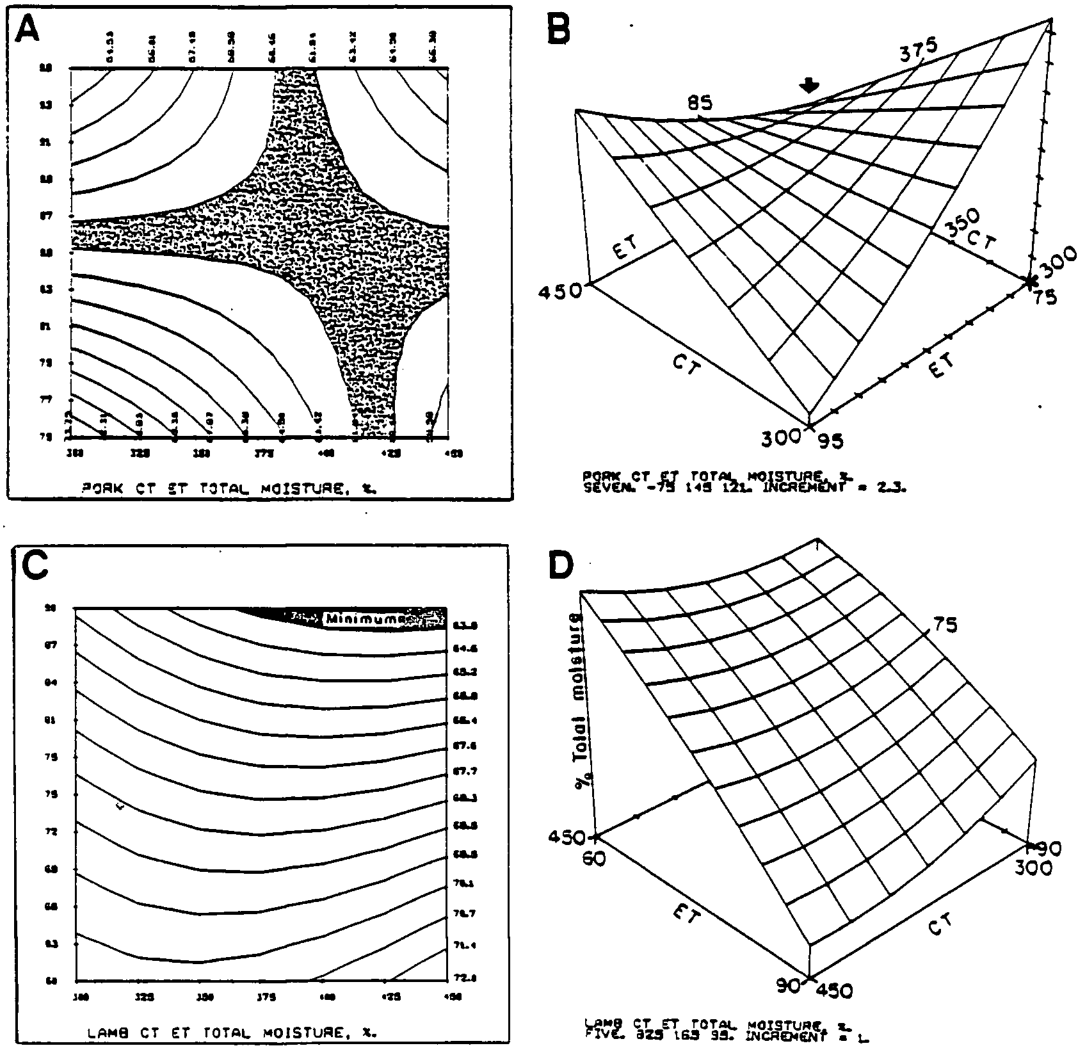


Fig. 3.6. Pork and lamb loin roast contour plots and response surfaces with independent variables, cooking temperature (CT, °F, X-axis) and endpoint temperature (ET, °C, Y-axis) for the response variable (Z-axis) total moisture (%), for pork (A; B) and lamb (C; D).

415°F (213°C) and 425°F (218°C) CT for the low ETs and between 380°F (193°C) and 395°F (202°C) for the higher ETs. A more detailed evaluation of the plot reveals that along 300°F (149°C) CT at the lower ETs, there is more total moisture retained. This is clearly noticeable as a "pointed corner" (arrow denotes corner) in the response surface (Fig. 3.6B). The opposite corner also peaks and the valley or plateau region is also visible in this surface viewpoint. The peaked area in the high CT-high ET region ties together with the short cooking time and low evaporation losses in this region. Evaluation of the contour plot and response surface analysis (RSA) permits the recommendation of a CT between 400-450°F (204-232°C) and an endpoint temperature between 87 and 95°C, in order to obtain a fairly moist, but well-cooked roast.

The total moisture (%) contour plot for lamb (Fig. 3.6C) shows a slightly curved set of contour lines that are concentrically moving outwards from a minimum value of 63.3% to a high of 72%, as opposed to the saddle found in the pork. When the surface (Fig. 3.6D) is viewed from the opposite side to what has usually been shown before (viewpoint 5 versus 1), it is seen as a more pronounced, sharply declining plane, with a higher percentage total moisture loss (less retention) along the high ET areas, across the whole CT range. The longer the meat is subjected to the heat treatment, the less moisture is retained (Fig.3.6A-3.6D) and the drier one would expect the product to be.

Pork and lamb total moistures (%TM) show that the quadratic model and the response surface are useful in explaining what is happening in terms of the response of the dependent variable to the effect of the two independent "heat" variables ($P \leq 0.20$). The percent total cooking loss (%TCLOSS)($P=0.11$) for pork is close to the $P=0.10$ cut-off value for significance, and also offers a logical explanation about what is happening, namely, when the percent total cooking loss is high, the %TM is low.

For both pork and lamb, the longer the cooking time, the lower the %TM, but the %TM levels off in an iso-moisture region. The valley changes direction and this may be due to the change in the water-holding capacity of the muscle proteins. The protein peptide chains unfold at internal temperatures below 50°C and form unstable cross-linkages followed by partial denaturation of the sarcoplasmic proteins. The myofibrillar proteins become tougher and there is a loss in WHC. Collagen shrinks between about 61-63°C and softens as the secondary (helical) structure of the protein is destroyed. Above 80°C final coagulation of the myofibrillar and sarcoplasmic proteins occurs, with corresponding expulsion of water. Due to the temperature gradient phenomenon (Cloke et al., 1981) not all the proteins undergo denaturation and coagulation simultaneously. This could be partly responsible for the iso-moisture region.

Expressible moisture index. The lamb contour plot (Fig. 3.3C) and response surface (Fig. 3.3D) both show a peak in the maximum CT-maximum ET area. A high EMI value means a low water-holding capacity (WHC). The highest numbers (Fig. 3.3C) are found in the maximum CT-maximum ET area where the contours are approaching a maximum region (shaded area), indicating less WHC here. Pork EMI values were not significantly affected by the CT-ET combinations used.

Total nitrogen and protein solubility. For pork (Fig. 3.7),

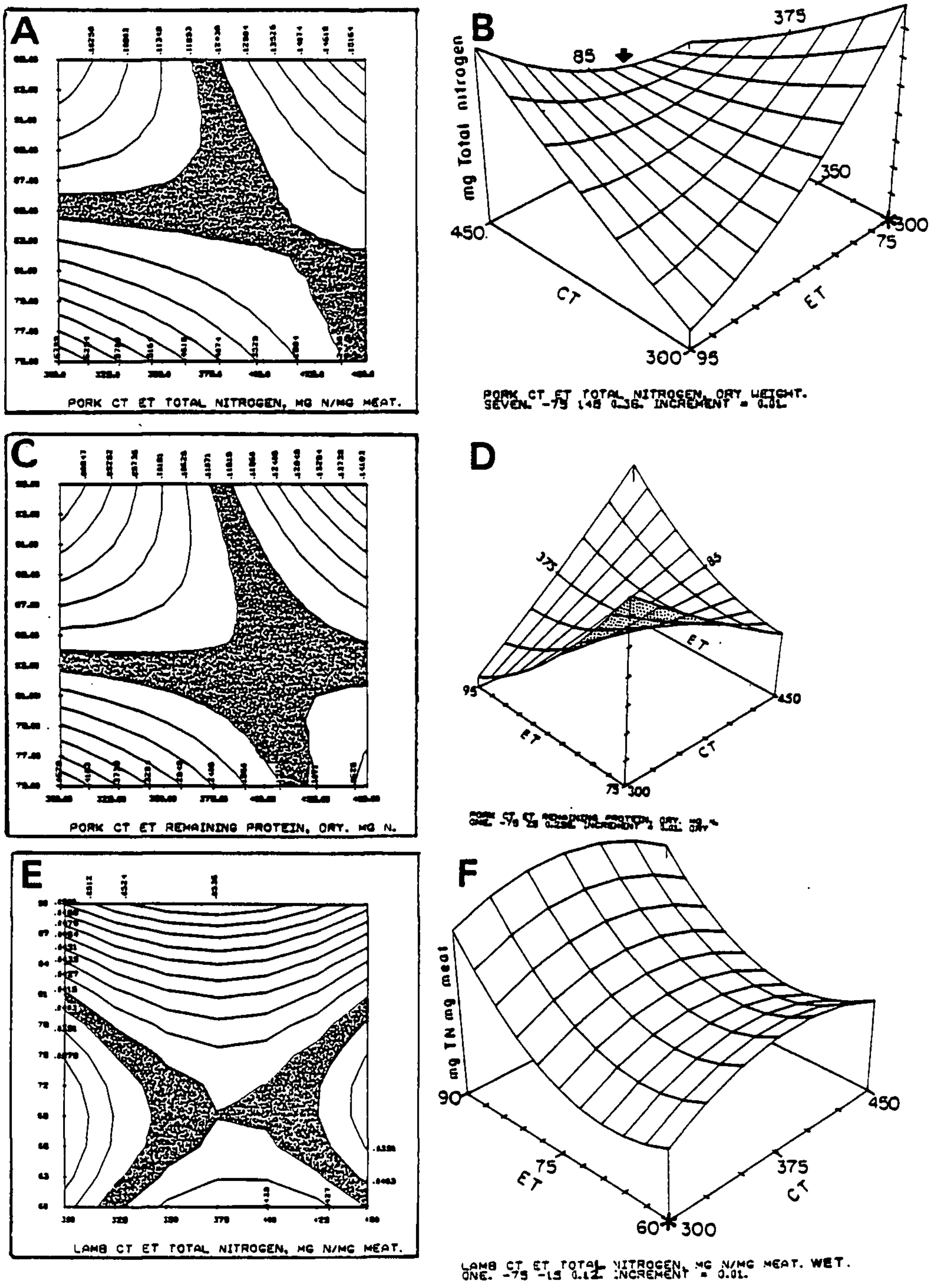


Fig. 3.7. Pork and lamb loin roast contour plots and response surfaces with independent variables, cooking temperature (CT, °F, X-axis) and endpoint temperature (ET, °C, Y-axis), for the response variables (Z-axis) pork total nitrogen (A; B), pork remaining protein (C; D)(both mg N/mg pork, dry weight basis) and lamb total nitrogen (mg N/mg lamb, wet weight basis)(E; F).

only the amount of total nitrogen (TN, mg N/mg pork, dry weight basis, P=0.001) and the amount of remaining protein (REM) are significant (P=0.001 level). The quadratic regression model, the contour plots and 3-dimensional surfaces explain the response of these two variables to the CT and ET. The pork contour plot (Fig. 3.7A) shows that the amount of total nitrogen retained decreases as one moves from 300°F (149°C) towards 450°F (232°C) CT, on the 75°C ET line. For a given CT, for example 325°F (163°C), as one increases ETs, the amount of total nitrogen retained decreases. Around 85°C ET and between 400-425°F (204-218°C) CT, TN remains fairly stable as represented by the saddle (shaded, Fig. 3.7A). The lowest values for TN occur at the min CT-max ET corner with the best retention in the min CT-min ET corner (Fig. 3.7A and 3.7C). Fig. 3.7A of TN resembles the %TM (Fig. 3.6A) very closely, as Fig. 3.7B resembles Fig. 3.6B. The water-holding capacity of the proteins is altered through denaturation and coagulation, and the amount of moisture held varies in a proportional way with the amount of total nitrogen retained. This could suggest that in the moist milieu of proteins (low CT-low ET and high CT-high ET) there is less severe damage done to the tertiary and quaternary structure of the protein backbones/chains. This results in less cross-bonding of amino acid side chains. The contour plot and response surfaces of the remaining protein fractions (dry weight)(Fig. 3.7C and 3.7D) for pork are almost identical to the TN ones, although the values are slightly different.

In lamb (Fig. 3.7), the dry weight basis values for total nitrogen did not appear to differ significantly. This relates to the amount of moisture present in the samples, as discussed previously

(Fig. 3.7E-3.7F). The quadratic regression model, the plots and 3-dimensional surfaces explain the response of total nitrogen on a wet weight basis to the significant effect of CT and ET. The saddle visible in Fig. 3.7E and 3.7F shows an area where the values are almost constant. This occurs at a wide array of temperatures. Fig. 3.7E shows the least amount of total nitrogen retained remaining almost at a constant low in the valley running between 66 and 75°C and stretching across the whole CT range, as one moves from 300°F (149°C) towards 450°F (232°C) CT (shaded area, Fig. 3.7E). For a given CT, for example 375°F (191°C), as one increases ETs (moving "upwards"), the amount of total nitrogen obtained or retained at first slightly decreases and then increases again. The least amount of protein over-coagulation would then be expected in the low CT-low ET and in the high CT-high ET regions.

Color. In pork, (Fig. 3.8A-3.8F), the CIE chromaticity coordinate z was significant (P=0.04), whereas x and y were not. In lamb (Fig. 3.8A-3.8F) the chromaticity coordinate x and z values were significant. It is necessary to consider all these values as the information is required for the CIE chromaticity diagram. These coordinate ranges would fall in the white CIE Illuminant C area (deMan, 1980), but towards the purplish-pink region. The contour plot of the pork coordinate z (Fig. 3.8E) and its corresponding response surface (Fig. 3.8F) show another saddle. However, they are the least informative of the "responses" being considered. The lamb contour plots and response surfaces for these color measurements (Fig. 3.9A-3.9H) are more informative. The three CIE chromaticity coordinates (Fig. 3.9A, 3.9C, and 3.9E) show that maximum areas have

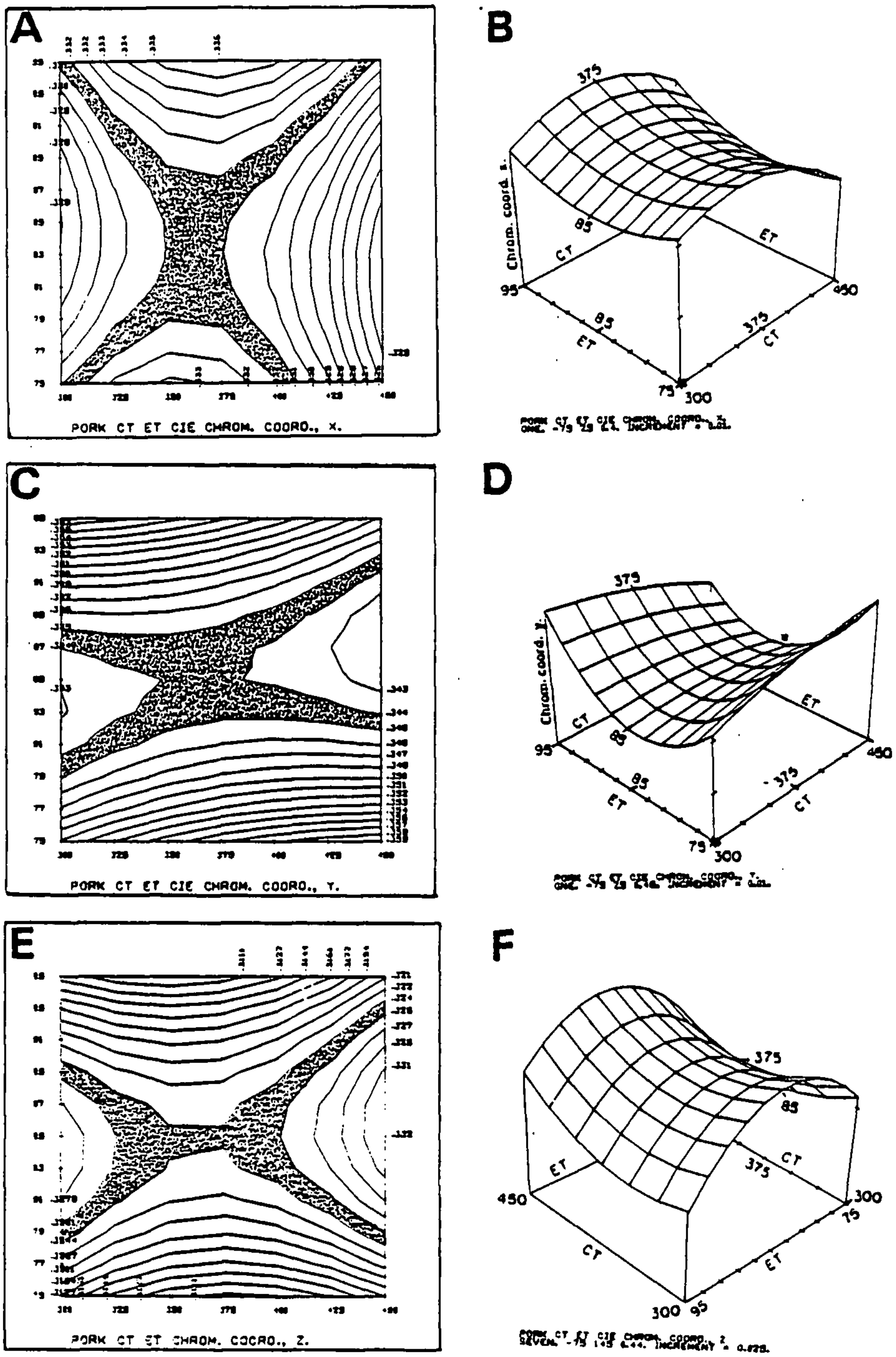


Fig. 3.8. Pork loin roast contours plot and response surfaces with independent variables, cooking temperature (CT, °F, X-axis) and endpoint temperature (ET, °C, Y-axis), for the C.I.E. chromaticity coordinate response variables, x (A and B); y (C and D) and z (E and F).

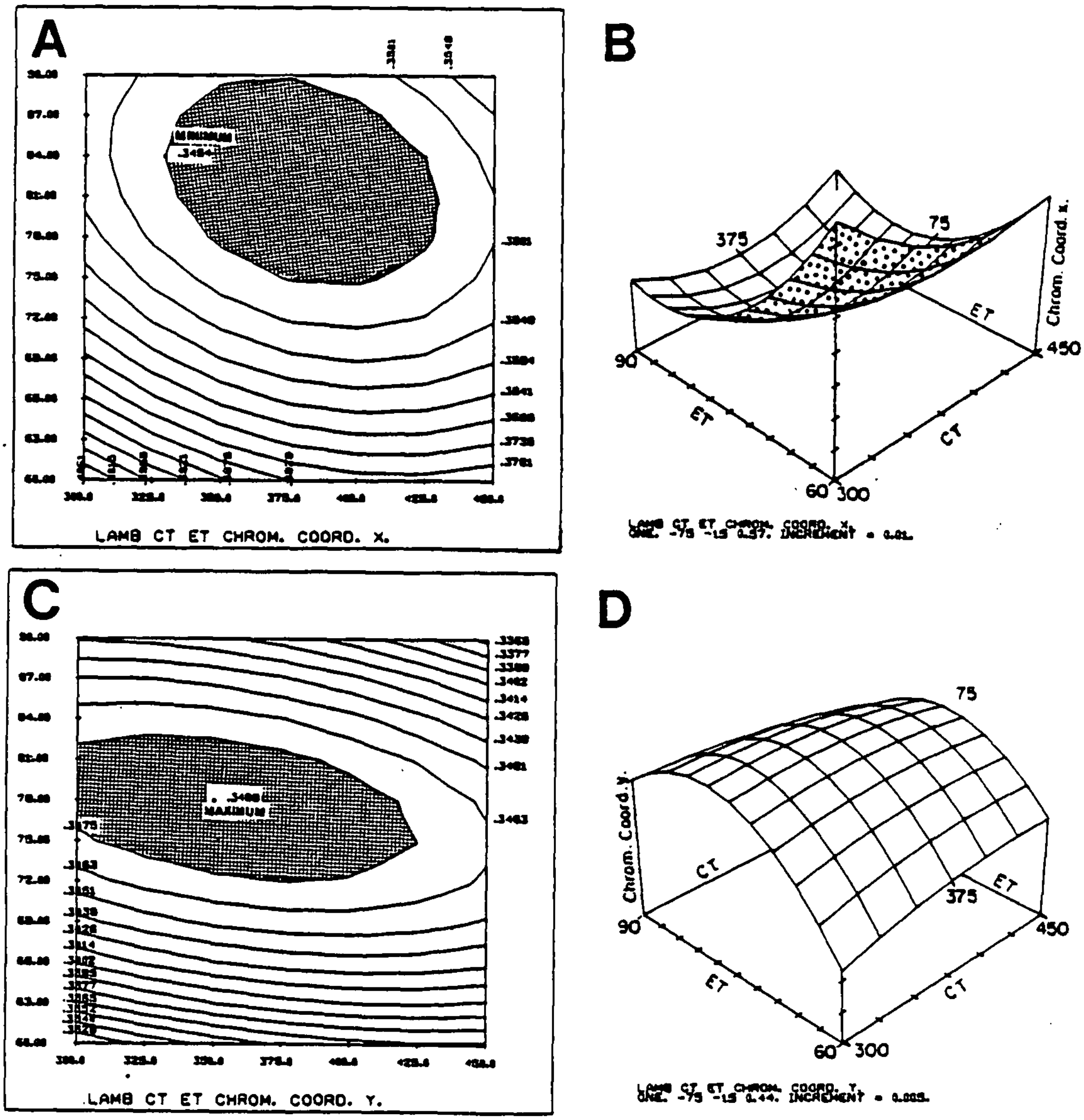


Fig. 3.9. Lamb loin roast contours plot and response surfaces with independent variables, cooking temperature (CT, °F, X-axis) and endpoint temperature (ET, °C, Y-axis), for the C.I.E. chromaticity coordinate response variables, x (A and B); y (C and D).

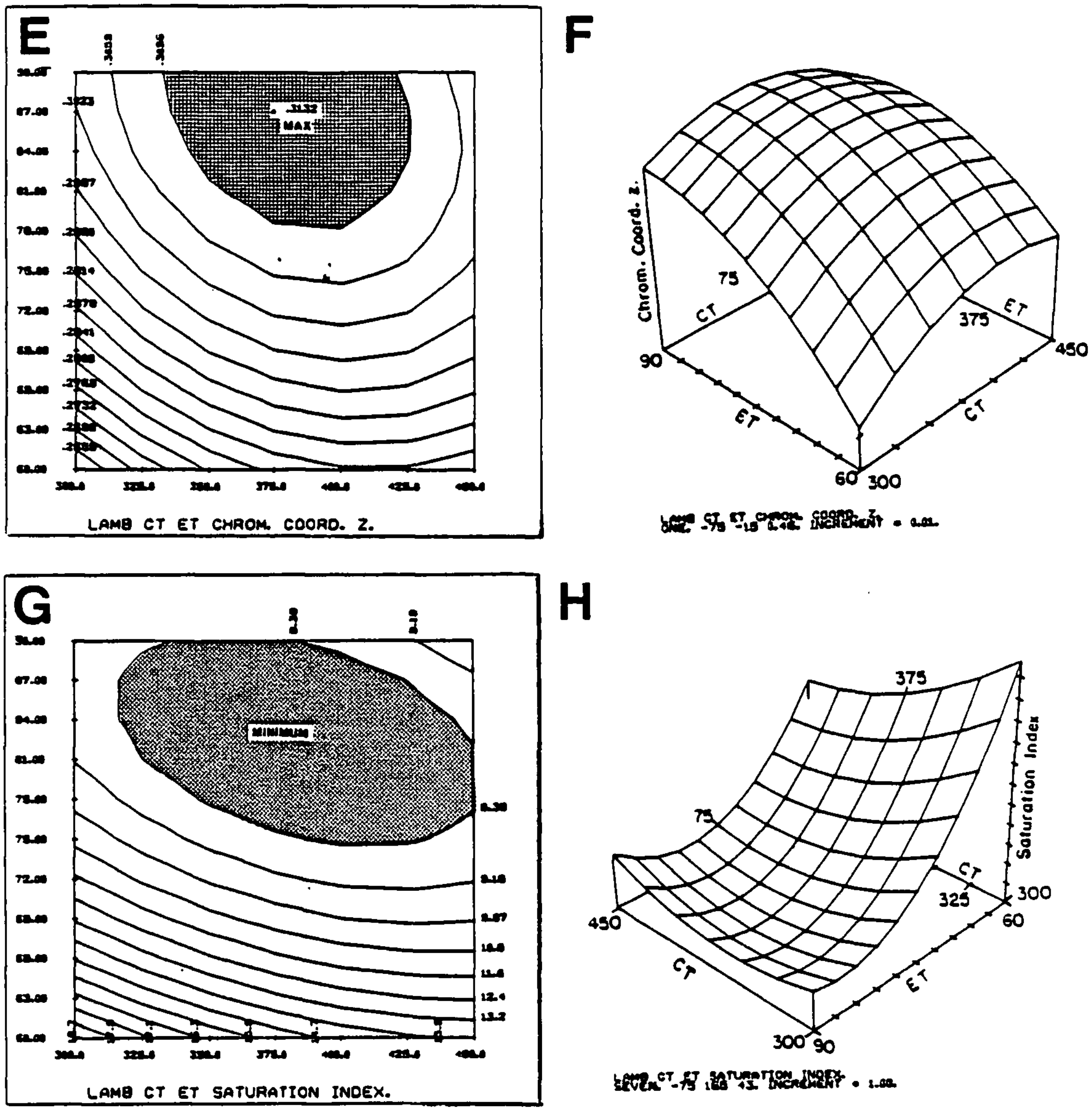


Fig. 3.9. Lamb loin roast contour plot and response surfaces with independent variables, cooking temperature (CT, °F, X-axis) and endpoint temperature (ET, °C, Y-axis), for the C.I.E. chromaticity coordinate response variable, z (E and F) and for saturation index (G and H).

been encountered (shaded). Both coordinates x and z show peak values, but these two items are not important without the y coordinate, needed to plot the values on CIE chromaticity diagrams, hence the inclusion of the contour plot and response surface (Fig. 3.9C and 3.9D) for the y-value. The y-surface (Fig. 3.9D) shows a peak even though the values shown on the contour levels are so close together. When using the peak values for plotting the x and y coordinates, the computed maximum x, y and z values are 0.345, 0.349 and 0.313 respectively. They are located in the CIE Illuminant C area, towards the purplish-pink region (deMan, 1980). The saturation index information (Fig. 3.9G and 3.9H) shows a slight bowl-valley configuration, with the minimum region clearly shown (shaded, Fig. 3.9G; arrow, Fig. 3.9H). The valley falls slightly above the center point CT-ET area, across the CT range, from about 78°C ET and upwards to 90°C. The formula for this variable includes the Hunter aL and bL values - redness and yellowness values.

Sensory evaluation. According to the data, juiciness (Fig. 3.10) was the only pork sensory quality characteristic (P=0.10) significantly affected by the CT-ET combination. This is in agreement with the % total moisture and % total cooking loss information referred to previously. Juiciness was judged according to a 1-5 scale with the "juicy" value in the middle of this range. The contour plot (Fig. 3.10A) and the response surfaces (Fig. 3.10B, 3.10C and 3.8D) emphasize a definite valley in the region of 2.5-3. When the ET is low (below 80°C) or high (above 90°C) (shaded area), the juiciness values are high (above 3), whereas, the lowest juiciness values (below 2.5) are found at the highest CT 450°F (232°C) at virtually any

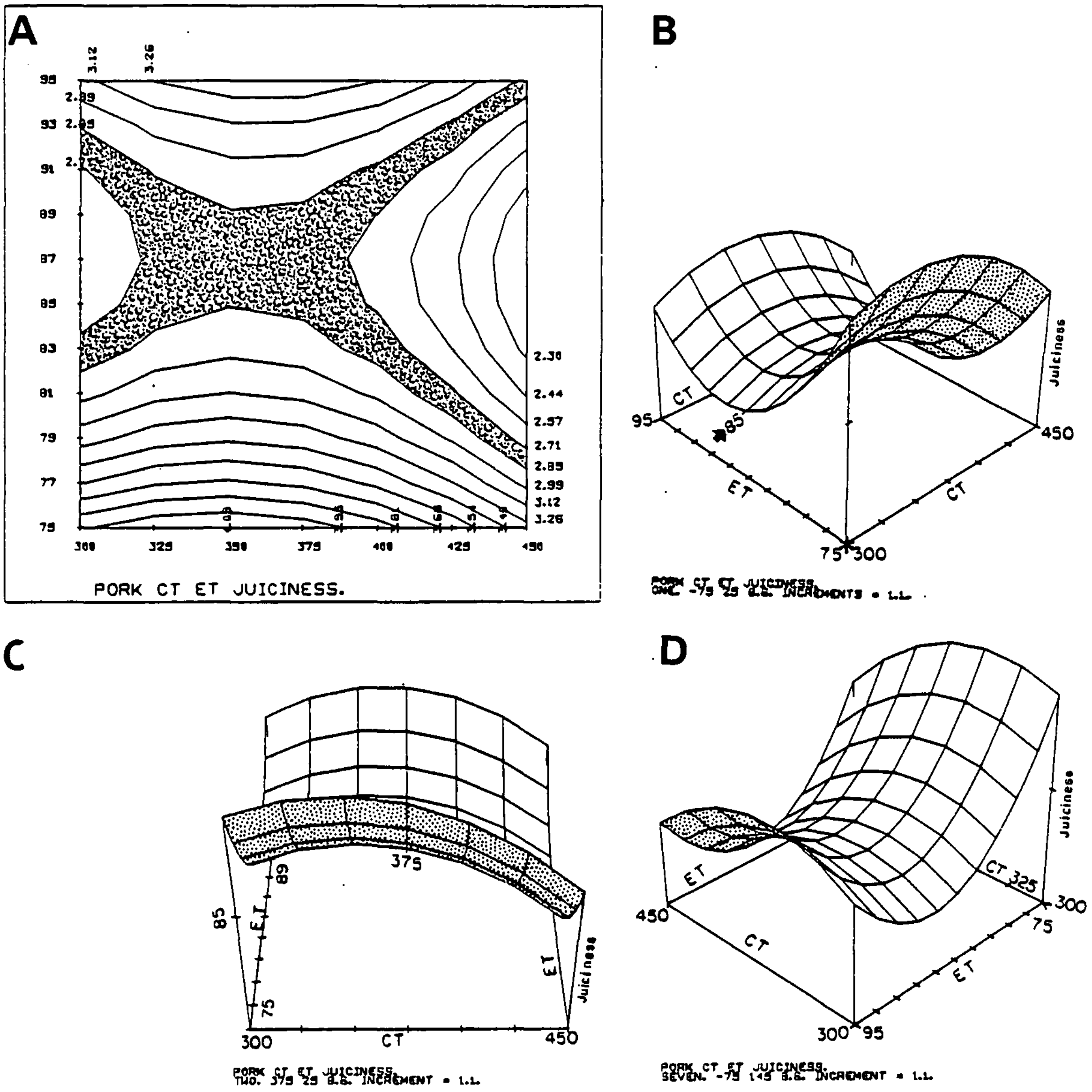


Fig. 3.10. Pork loin roast contour plots and response surfaces with independent variables, cooking temperature (CT, °F, X-axis) and endpoint temperature (ET, °C,Y-axis) for the response variable (Z-axis) sensory juiciness (A; B; C=VP two; D=VP seven).

selected ET. There is a wide saddle area (shaded on Fig. 3.10A and arrows on Fig. 3.10B-3.10D) around the maximum range covering the 80-84°C ET range, and the total CT range.

Two related lamb sensory quality characteristic variables were significant, namely doneness ($P=0.01$) and color ($P=0.10$)(Fig. 3.11). The doneness contour plot (Fig. 3.11A, shaded area) and the response surface (Fig. 3.11B) show that lamb cooked to higher ETs (79°C and above) was judged to be more well-done, especially with higher CTs 375°F (191°C) and above). The relationship between the lower CTs and ETs and the higher ones is almost linear, with the higher values from approximately 75°C and above. The peak is almost attained, with the stationary point at 3.18 (Fig. 3.11B), a value near the "neither-overcooked, neither undercooked" score value of 3. Judging from the contour lines (Fig. 3.11A), the ET is again more important than the CT, as more lines are crossed when one moves upwards vertically from the 60°C ET line.

The lamb sensory color minimum and maximum values are 0.4 and 4.0, respectively. The peak area (shaded) is at 4.0 (slightly overcooked), according to the contour plot (Fig. 3.11C), and this peak is obvious in the response surface (Fig. 3.11D). This is almost in the same area as for doneness (Fig. 3.11A). The lowest scores are in the minimum CT-minimum ET corner, or the most reddish-pink area and typical of undercooked meat.

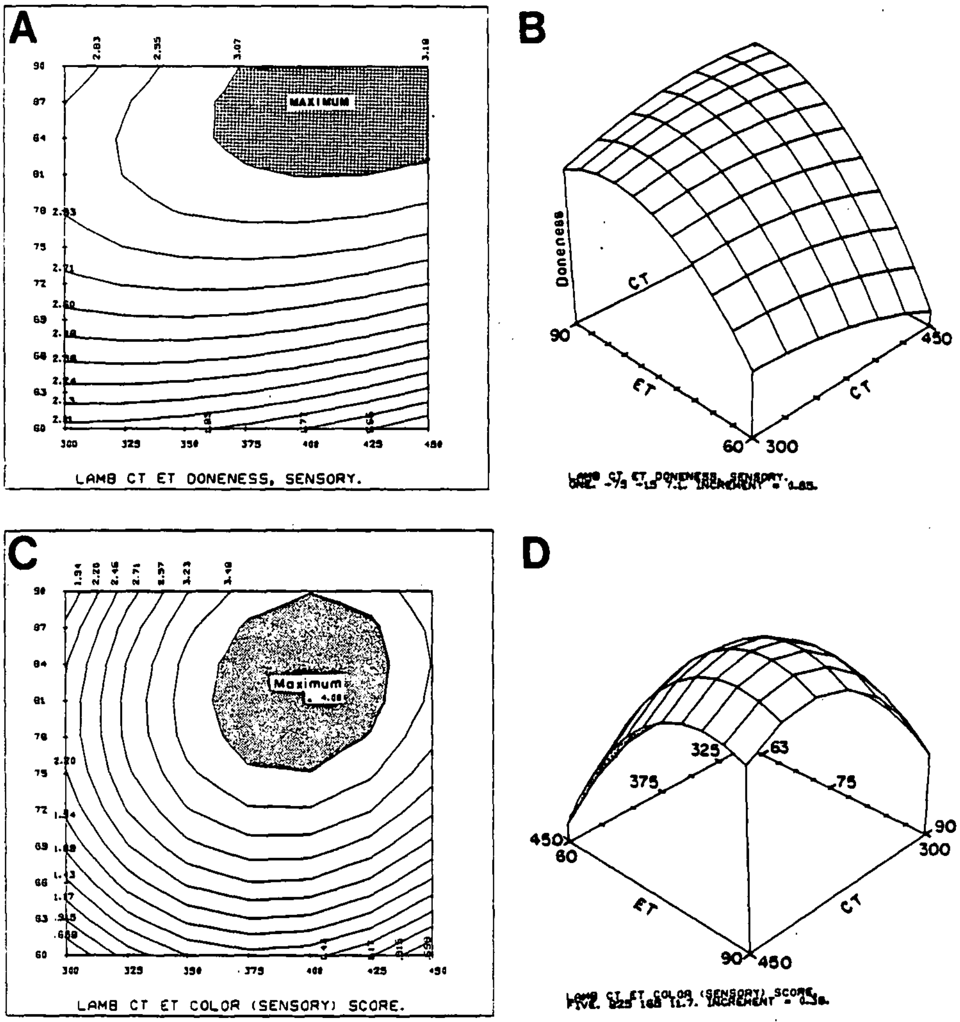


Fig. 3.11. Lamb loin roast contour plots and response surfaces with independent variables, cooking temperature (CT, °F, X-axis) and endpoint temperature (ET, °C, Y-axis), for the response variables (Z-axis) sensory doneness and color.

APPLICATIONS AND IMPLICATIONS

The information gleaned from contour plots and response surfaces of both significant and non-significant variables may be put to practical use in industry, by institutions and the consumer alike. The contour plots themselves are valuable resources as they can be used for estimating the range of response variable values relevant for a particular CT-ET combination of interest. For example, the nature of the pork juiciness plots (Fig. 3.10) shows that the trained panel could not distinguish between the effects of a range of CT-ET combinations. Thus, other important factors may be used for decision-making such as fuel saving measures and economy factors.

This integration of the CCRD and RSM might be applied to other dependent variables as well, with similar applications and implications. This central composite rotatable design (CCRD) may be used for predicting the behavior of selected dependent variables of roast pork and lamb loins, but also, perhaps more importantly, for examining the effect of the CT-ET variables on all the variables tested and using the contour plots and response surfaces to aid decision-makers, providing the areas being explored remain within the temperature ranges tested.

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Chapter 4

THE ABILITY OF A TWO-FACTOR QUADRATIC REGRESSION CENTRAL COMPOSITE ROTATABLE DESIGN WITH RESPONSE SURFACE ANALYSIS TO PREDICT TURKEY BREAST AND THIGH MEAT QUALITY CHARACTERISTICS[1]

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TURKEY QUALITY

(submitted to Poultry Science)

ABSTRACT

THE ABILITY OF A TWO-FACTOR QUADRATIC CENTRAL COMPOSITE ROTATABLE DESIGN WITH RESPONSE SURFACE ANALYSIS TO PREDICT TURKEY BREAST AND THIGH MEAT QUALITY CHARACTERISTICS. I.B. ZONDAGH, Z.A. HOLMES AND K. ROWE, Dept. of Foods and Nutrition, and Dept. of Statistics, Oregon State University, Corvallis, OR 97331.

A two-factor quadratic central composite rotatable design and corresponding response surface analysis were applied to frozen half-turkey roasts, using cooking temperature and endpoint temperature as the two independent variables, successfully predicted significant dependent variables. Prediction ability was checked with control turkeys (350°F/177°C to 80°C). The dependent variables of heating rates (°C/g, °C/min, °C/g/min), total cooking and evaporation loss (%), cooking time (min), total nitrogen, low ionic strength and remaining protein (%, mg N/mg breast meat, dry weight basis) and non-protein nitrogen extract (mg N/mg breast meat, wet weight basis), and sensory panel thigh juiciness, were found to be significant. Contour plots and response surfaces were found useful in evaluating results.

INTRODUCTION

In the United States there is a definite consumer preference for turkey meat. Much has been written about the roasting methods, cooking temperatures and endpoint temperatures, cooking losses and palatability of turkey (Cornforth et al., 1982; Berry et al., 1980; Heine et al., 1973; Deethardt et al, 1971; Cash and Carlin, 1968; Goertz and Watson, 1964; Goertz et al., 1962; Goodwin et al., 1962; Goertz, et al., 1960; Goertz and Stacy, 1960), but none of the authors have taken the temperature-meat quality prediction approach reported here.

The objectives of this paper were to investigate the ability of a two-factor central composite rotatable design (CCRD), using cooking temperature (CT) and endpoint temperature (ET) as the independent variables, to predict selected chemical, physical and sensory quality characteristics considered important by the industry, researcher and consumer alike, and then to check the predicting ability of this CCRD model, as suggested by Hailey et al. (1980) and Villasmil et al. (1975). Response surface analysis (RSA) was also used simultaneously to evaluate the nature of the responses obtained, with the 13 CT-ET combinations used on previously frozen half-turkey roasts.

MATERIALS AND METHODS

Samples

Five month old Nicholas Large White turkeys (each half averaging 4022 g, 5.0% total nitrogen, 67.3% total moisture when tested) were obtained from the Oregon Turkey Hatchery via the Oregon State Univerity Poultry Science Department, Corvallis, Oregon. The turkeys used for the central composite rotatable design (CCRD) and the experiment checking the predictability of CCRD model (CKPM refers to checking predictability of model) had been fed on isonitrogenous and isocaloric rations (Savage and Nakaue, 1983).

The turkeys were slaughtered and processed at the Poultry Science Laboratory, Oregon State University. The whole turkeys were sawed in half and left and right halves individually double-wrapped in freezer bags and stored at $-18^{\circ}C$ until roasted. Samples (halves) for the cooking temperature-endpoint temperature treatments were defrosted 6 hr at $25^{\circ}C$, followed by 30 hr at $4^{\circ}C$. Cooked left turkey halves were used for total moisture, expressible moisture index and chemical analysis. The right roasted halves were prepared for sensory analysis and Warner-Bratzler shear test.

Statistical Design

A two-factor Central Composite Rotatable Design (CCRD) (Cochran and Cox, 1957) was chosen to allow maximum cooking and internal endpoint temperature coverage with the limited amount of sample available. The independent (X)-variables were the cooking (oven) temperatures (CT) and the internal endpoint temperatures (ET). The results obtained from the objective (chemical and physical) and subjective tests were regarded as the dependent (Y)-variables or responses. Table 4.1 shows the basic CCRD with its four points which constitute the 2-squared factorial (-1,-1), (1,-1), (-1,1) and (1,1); the four extra "star" points included to form the central composite design (-1.414,0), (1.414,0), (0,-1.414) and (0,1.414); and the five points that are added to the center to give approximately equal precision for estimated y-variables (responses) within a circle of radius 1 unit (Cochran and Cox, 1957). The corresponding values calculated to represent these various points are also given.

The CT range chosen for the CCRD experiment was 300 to 450°F (149 to 232°C) (customary household oven temperatures used) and the ET-range of the center of the breast cut was from 75 to 95°C. The corresponding center point CT-ET combinations were 375°F (191°C) and 85°C (Table 4.1). Two replications of the model were done, using the left sides versus right sides which resulted in 26 observations.

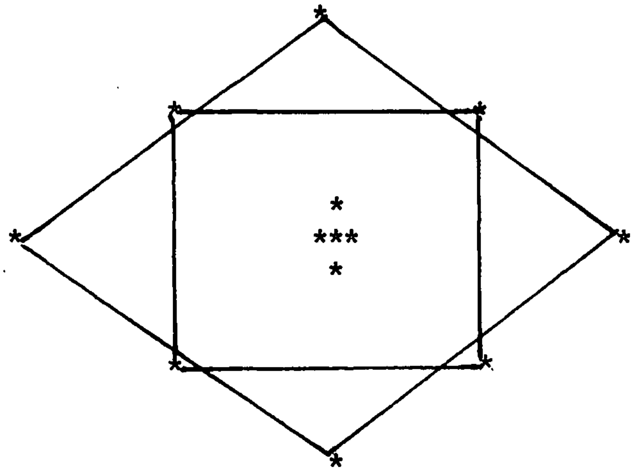
Sample Preparation

Each defrosted turkey half was placed on a wire rack in a foil-lined, aluminum roasting pan and baked in the center of a preheated, self-cleaning, 45-cm electric oven. CT-ET combinations were randomly allocated to the raw turkey halves. Muscles were excised from the roasted turkey halves for the various physical and chemical tests. After they were excised from the cooled, cooked

Table 4.1. Visual display of the turkey halves' cooking temperature-endpoint temperature combinations, used for this CCRD design with two independent variables. Cooking temperature is given in both °C and °F, with endpoint temperature only in °C.

Design Points	-1.414	-1	0	1	1
Cooking Temperature, °F	300	322	375	428	450
Cooking Temperature, °C	149	161	191	220	232

Design Points	Endpoint Temperature, °C
1.414	95.0
1	92.0
0	85.0
-1	78.0
-1.414	75.0



roast, they were stored in moisture proof wrapping until apportioning for the objective and subjective tests.

The six turkeys (CKPM) for checking the design were roasted at a cooking temperature of 350°F (177°C). They were taken to an endpoint temperature also not used in the design, 80°C. Other than that, these halves were treated and tested identically to the CCRD ones.

Testing Methods

Thirteen (total 26) paired turkey halves were roasted (Table 4.1) as, statistically, duplication of the design strengthens the results. Simultaneous chemical, physical and sensory testing was not possible due to the limited size of the thigh meat sample. The left halves were roasted initially, with the right halves being done within one month, resulting in a double set of information becoming available for the cooking losses and total cooking times (Y-variables) but not for the chemical or sensory tests. The left turkey halves were used for evaluating the following response variables: namely, total nitrogen, protein solubility, total moisture, and expressible moisture index. The right turkey halves were used for sensory and Warner-Bratzler (W-B) tenderness determinations.

Cooking data. The initial and final cooking weights of each turkey half roast were recorded. Total and drip cooking losses were calculated. Evaporation loss was calculated as the difference between the total cooking loss and the drip loss. Internal temperatures during the heating of the turkey roasts were monitored at the center of the pectoral superficialis muscle with a Leeds and Northrup W12

Temperature Recorder (Leeds and Northrup, Portland, OR), using a constantan-copper saber thermocouple. Heating rates were calculated as $^{o}C/g$, $^{o}C/min$, and $^{o}C/g/min$.

Warner-Bratzler shear values. Tenderness was determined according to Riffero and Holmes (1983). Shear values for the breast and thigh cuts were determined on the pectoralis profundus and semitendinosus muscles, respectively. Duplicate samples from each muscle portion were cut across the predominant longitudinal fiber direction using a 1.27 cm core meat sample on a Warner-Bratzler shear apparatus (25 kg x 50g dynamometer scale, G.R. Electric Mfg. Co., 1317 Collins Lane, Manhattan, KS).

Total moisture and water-holding capacity. Total moisture content was determined on duplicate 5 g cooked, chopped turkey samples, according to the AOAC vacuum oven method (AOAC, 1980). Duplicate 5 g chopped samples from each replication of the pectoralis superficialis muscle were used to evaluate moisture of the breast cut. Similar composite duplicate samples of the extensor femoris, vastus externus and biceps flexor cruris muscles were used to evaluate the thigh cut.

The method of Wierbicki and Deatherage (1958) was used to evaluate the water-holding capacity. The vastus externus and the pectoralis superficialis were used for the breast and thigh cuts, respectively. Triplicate sets of meat and juice areas of the pressed muscle were measured with a Li-Cor LI-3100 Area Meter (Li-Cor, Inc./Li-Cor, Ltd., Lincoln, Nebraska 68504). The expressible moisture index (EMI) values were calculated as the ratio between the mean meat and mean juice areas.

Total nitrogen and protein extractions. Total nitrogen content was determined on duplicate samples of the finely chopped cooked and raw turkey breast and thigh muscles, according to the micro-Kjeldahl method (AOAC, 1980). The data were expressed as mg N/mg meat, wet and dry weight basis. The extraction method used for both low ionic strength (LIS) soluble protein extract and non-protein nitrogen (NPN) extract/fraction was a modification of work reported by Hegarty et al. (1963), as only a 2 g sample was used and reagent volumes were adjusted to this weight.

Data were used to calculate percent total nitrogen, sarcoplasmic fraction (LIS - NPN), "remaining" protein fraction (TN - (LIS + NPN)) which is thought to consist of the remaining fibrillar protein, high ionic strength soluble protein fraction(s), alkali-soluble protein and connective tissue residue (Hegarty et al., 1963).

Sensory Tests

Eight Oregon State University staff members were selected through preliminary screening and trained to evaluate turkey thigh and breast cubes for the four sensory characteristics. They evaluated the tenderness (5=very tender, 1=very tough), flavor (5=very pronounced meaty flavor, 1=no meaty flavor), doneness (5=very overcooked, 1=very undercooked), and juiciness (5=very juicy, 1=very dry) of the cooked turkey muscle. Coded cubes of approximately 1.50 cm were excised from the pectoralis superficialis breast muscle and from the biceps flexor cruris, extensor femoris and vastus externus thigh muscles and were presented to each panelist. No more than six samples for the CT-ET treatments were presented at one test period. The samples were evaluated at room temperature (21°C).

Statistical Data Analysis

The following quadratic polynomial regression equation (model) (Eq. 1) was used for evaluating the individual Y-variables of the turkeys used for the CCRD. There were 42 response (dependent) variables for the turkey halves, including two dummy variables of weight used to check the statistical procedure and its results.

$$\hat{y} = \text{Y-hat} = A + B{*}CT + C{*}ET + D{*}CT{*}CT + E{*}ET{*}ET + F{*}CT{*}ET \qquad (1)$$

where, $\hat{y}$ = Y-hat = the predicted Y-variable's value;

CT = Independent variable, cooking temperature, °F, X_1;

ET = Independent variable, endpoint temperature, °C, X_2;

and A, B, C, D, E and F are the regression coefficients.

Computations were done on the CDC Cyber 170/720 computer (NOS 2.2 operating system) at the O.S.U. Milne Computer Center, Corvallis. The REGRESS subsystem of the Statistical Interactive Programming System (SIPS)(Rowe and Brenne, 1982) was used for single and double regressions. For the single regressions, the quadratic regression model, analysis of variance table (for regression and residual error sources), t-values, Y-hats, residuals and histograms of residuals were obtained. The sums of squares and variance values for each Y-variable were also calculated, using SIPS. These values were used to calculate F-values and to test for lack of fit and the error term applicable. For these single regressions, significance was determined at the 10% level of probability for the Mean Square Regression/Mean Square

Residual F-values, whereas the 20% level was used for initial screening for the Mean Square Lack of Fit/Mean Square Pure Error.

The F-value evaluation procedure for the double regressions is shown in Table 4.2 in sequential order. The paired left and right side halves (duplicates) were first compared to each other to ascertain whether or not they were similar. Then the model (two independent variables) or "real/actual" regression (CT*ET), and finally, the interaction of sides (run*regression) were checked, for the major source(s) of variation and for calculating the lack of fit and pure error components of the residuals sum of squares and mean squares. Histograms of the residuals were evaluated to look for outliers and these observations were then removed from the data sets before redoing the regressions and F-values.

Regression coefficients were used to create the Contour Plots and Response Surfaces, using plotting/graphics routines called "SURCONN" (Fuhrer, 1984). For each significant variable, a two-dimensional contour plot and three-dimensional response surface views were drawn/plotted and evaluated. Only the most informative are presented. This was usually the contour plot without grid lines and with response surface viewpoints one, three and five. The CT-ET variables are located along the traditional X- and Y-axes of normal graph conventions while the response variable falls along the Z-axis which forms perpendicular "legs" and adds the third dimension to the flat surface or plane formed by the X-Y axes. Shaded areas indicate minimum or maximum responses. For the response surfaces, the Z-axis shows the response height and nature of the surface for the variable. In the second line of the response surface label, the viewpoint used

Table 4.2. Double regression ANOVAs to illustrate F-ratio calculations.

Source of Regression	DF	Mean Square (MS) ratios for calculated F values	Ftable P-value and evaluation
Run (Left vs right side)	1	Run MS/Residual MS	0.10. If NS, sides do not differ.
Model or regression (CT*ET)	5	CT*ET MS/Residual MS	0.10. If NS, model or design is not suitable. Significance is desirable.
Run*Regression (Interaction of sides)	5	Run*Regression MS/ Residual MS	0.10. If significant, indicates trouble, as there is interaction of sides. The 2 sides regress differently.
Residual	14		
Lack of Fit	6	MSLF/MSPE	0.20. If N.S., use Residual MS as denominator for above F-calcs. If Significant, use LFMS as denominator above.
Pure Error	8	(evaluated first)	

(1-8) is given first, followed by the CT and ET and values of the response variable that represent the viewpoint being used. This is followed by the interval or increment size, should one wish to estimate the height above the base (Zondagh, 1984).

The method used for checking prediction accuracy of model (CKPM). The values for each of the significant regression coefficients for the CCRD turkey response variables (Table 4.3) were substituted for the A-F coefficients in the quadratic regression equation (Eq. 1), with CT = 350^oF (177^oC), and ET = 80^oC (Table 4.5). The predicted or estimated response value, Y-hat, for the particular variable was calculated and then compared to the approximated value read from the contour plot, using a 350^oF (177^oC) CT and a 80^oC ET coordinate (for example, Fig. 4.2A, 4.2C and 4.2E). This was followed by the checking procedure (CKPM) whereby the experimentally-obtained and tabulated laboratory data for the control turkey halves were used to compare predicted with experimentally-obtained values (Table 4.5).

RESULTS AND DISCUSSION

Cooking time (min), heating rates ($^oC/g$, $^oC/min$, $^oC/g/min$) and total cooking and evaporation loss (%) were significantly ($P \leq 0.10$) influenced by CT-ET combinations, together with certain nitrogen fractions and thigh juiciness (the only significant sensory score for breast or thigh) (Table 4.4). The significant nitrogen fractions are non-protein nitrogen (NPN) (mg N/mg sample, wet weight basis), total

Table 4.3. Quadratic regression model coefficients for turkey breast total nitrogen, protein extractions, heating rates and cooking data and for turkey thigh juiciness.

	A (constant)	B	C	D	E	F
<u>Turkey breast</u>						
Non-protein nitrogen fraction, mg N/mg meat wet weight basis	- 0.005083	- 0.00008084	0.0005773	0.0000001067	- 0.000003673	0.00000007155
Total nitrogen, mg N/mg meat dry weight basis	- 0.3469	- 0.0009854	0.01547	- 0.0000004031	- 0.0001184	+ 0.00001476
Total nitrogen, % dry weight basis	- 34.69	- 0.09854	1.547	- 0.00004031	- 0.01184	0.001476
Low ionic strength soluble fraction, mg N/mg meat, dry weight basis	0.007439	- 0.0005069	0.002418	0.0000006353	- 0.00001514	0.0000003533
"Remaining" protein fraction mg N/mg meat, dry weight basis	- 0.4284	- 0.00005023	0.01256	- 0.000001372	- 0.00009514	0.0000122

Table 4.3. Quadratic regression model coefficients for turkey breast total nitrogen, protein extractions, heating rates and cooking data and for turkey thigh juiciness (continued).

	A (constant)	B	C	D	E	F
Turkey breast						
Cooking loss total, %	- 61.85	0.2150	0.4535	- 0.0004589	- 0.003040	0.001850
Cooking loss evaporation, %	170.7	- 0.1423	- 3.543	- 0.0004157	0.011590	- 0.00571
Cooking time, min	902.0	- 2.837	- 5.969	0.002277	0.04299	0.005682
Heating rate (oC/g)	0.08128	- 0.0003739	0.00006681	0.0000001794	- 0.000005771	0.000002817
Heating rate (oC/min)	- 4.438	0.009598	0.07375	0.000004632	- 0.0002177	- 0.0001233
Heating rate (oC/g/min)	- 0.0002065	- 0.0000002859	0.000009102	0.000000002192	- 0.00000004941	- 0.000000008442
Turkey thigh						
Juiciness[1]	6.368	- 0.01088	0.007844	0.000009517	0.000002999	- 0.00004165

[1] Juiciness: 1 = very dry; 2 = very juicy

nitrogen, low ionic strength (LIS), and remaining protein fraction (mg N/mg meat, dry weight basis). Note that the second independent variable for thighs is cooking time and not endpoint temperature (ET).

Analysis of Variance

Eleven of the 42 listed variables (total includes the two initial weight and enzyme weight dummy variables) are significant ($P \leq 0.10$) (Table 4.4). This indicates that the quadratic regression model and the CCRD are suitable for these data and that the corresponding response surfaces and the CCRD explain the variability that is being observed in the various CT-ET combinations. The nature of this variability in the CT-ET combinations is explained by the two-dimensional contour plots and the three-dimensional response surfaces.

Table 4.5 lists all the significant, estimated Y-hat's partial regression coefficients for the quadratic model shown in Eq. 1. These may be used to predict response values for the significant Y-variables at other CT-ET combinations falling within the CT-ET ranges used in this study by substituting the values for A-F for these six regression coefficients and using ^{o}F for CT and ^{o}C for ET. This might be of special interest to the meat industry and/or institutions to predict yields. In this paper, the coefficients for the significant variables were applied to predict the values of dependent variables, using the CKPM control turkey halves, cooked at 350^{o}F (193^{o}C) to 80^{o}C (Table 4.5).

The following 9 turkey breast variables show calculated Mean Square Lack of Fit/Mean Square Pure Error (MSLF/MSPE) F-values that

Table 4.4. "Checking" prediction of model (CKPM) results compared to contour plot ranges/values and laboratory/experimentally-obtained data for the significant dependent quality variables for roast turkey halves.

Predicted Y or dependent variable $\hat{y}$	n	Predicted value using coefficients	Experimental Mean Value
Total Cooking Loss, %	6	25.81%	25.77 ±
Evaporation Loss, %	6	20.59	18.36
Cooking Time, min.	6	144.7	147.92
Heating Rate, °C/g	6	0.0196779	0.0175167 ± 0.1185209 x 10^{-2}
Heating Rate, °C/min	6	0.54304	0.5232 ± 0.0563
Heating Rate, °C/g/min	6	0.00013754	0.00012 ± 0.17426 x 10^{-4}
Sensory Juiciness (thigh)	5	3.2063461	2.52 ± 0.48
TN, dry weight	4	0.15195025	0.15081825 ± 0.7172146 x 10^{-2}
NPN, wet weight	4	0.004374	0.0053665 ± 0.990249 x 10^{-3}
LIS, dry weight	4	0.0142847	0.0009745 ± 0.1518516 x 10^{-2}
REM, dry weight	4	0.1234548	0.118142 ± 0.01085278
TN, dry weight, %	6	15.1950	

Table 4.5. Analysis of variance of significant variables for frozen half-turkeys for the two-factor central composite rotatable design (CCRD).

Y-variables	P-values/Significance values Turkey Breast	 Turkey Thigh
Initial weight, g (dummy variable)	N.S.[a]	—[b]
Heating rate, °C/g	0.06[c]	—
Heating rate, °C/min,	0.01	—
Heating rate, °C/g/min	N.S.	—
Total cooking loss, %	0.09	—
Drip loss, %	N.S.	—
Evaporation loss, %	0.03	—
Cooking time, min	(0.0001)[d]	—
Expressible moisture index	N.S.	N.S.
Percent total moisture	N.S.	N.S.
Warner-Bratzler, lb	N.S.	N.S.
Total nitrogen and %, wet weight	N.S.	N.S.
Low ionic strength, wet weight	N.S.	N.S.
Non-protein nitrogen, wet weight	0.01	N.S.
Sarcoplasmic protein fraction, wet weight	(0.118)	N.S.
Remaining protein fraction, wet weight	N.S.	N.S.
Total nitrogen and %, dry weight	0.06	N.S.
Low ionic strength, dry weight	0.02	N.S.
Non protein nitrogen, dry weight	(0.123)	N.S.
Sarcoplasmic protein fraction, dry weight	N.S.	N.S.
Remaining protein fraction, dry weight	0.05	N.S.

[a] N.S. means "Not Significant"
[b] -- means "Not Done"
[c] Double regressions were done on the cooking loss data, cooking times and heating rates for turkey.
[d] ( ) means "close to P=0.10"

are significant (ANOVAs not shown), ($\underline{P}<0.20$ level): heating rate (^{o}C/min), total cooking loss (%); total moisture, (%); total nitrogen (in mg and %TN), LIS, and sarcoplasmic protein fractions (mg N/mg meat, wet weight basis) and, sarcoplasmic protein extract (mg N/mg sample, dry weight basis). There were no significant values for sensory variables. Turkey thighs showed significant MSLF/MSPE F-values for the four dependent variables: expressible moisture index (EMI), sarcoplasmic protein (mg N/mg meat, wet weight basis) and LIS (mg N/mg meat sample, dry weight). There were seven situations whereby it was not possible to calculate the MSLF/MSPE values, due to negative Lack of Fit sums of squares (SS) and mean squares (MS). In these cases, the residual mean squares were used as the error terms, instead of the MSPE terms. The significant thigh MSLF/MSPE total is 11, making a total of 19 out of 42 variables tested (45%).

The negative lack of fit of SS and MS mentioned above indicates that the use of cooking time (min) as the second independent variable for thigh rather than ET was not suitable, due to the variability within the cooking time values for the center point observations. This, in itself, is due to the differences in initial weights of the turkey halves. Judged overall, there is very slight indication of variability between the double set of cooking loss data and the single regression sets for sensory evaluation, and most between the protein solubility data. This would seem to emphasize the advantages of the double regression procedure.

Contour Plots and Response Surfaces

These computer-generated two-dimensional plots and three-dimensional surfaces provide a very useful visual image of the relationships found between the CT-ET combinations and the Y-variable under discussion.

Heating rate (^{o}C/g) (Fig. 4.1A) shown in the contour plot indicates values close to 0.02. This dependent variable has calculated minimum and maximum values of 0.017 and 0.024 respectively. A saddle (shaded area) and iso-heating rate region is noticeable on the contour plot (Fig. 4.1A), but it is not as pronounced on the response surface (Fig. 4.1B, arrows). This is due to the narrow range between the minimum and maximum values.

When heating rate ($P \leq 0.10$) is calculated as ^{o}C/min, it is clearly evident from the contour plot (Fig. 4.1C) that the lines are only slightly curved (shaded, Fig. 4.1C). This heating rate increases linearly, and shows a decided increase above CT of 350^{o}F (191^{o}C), for all ETs (Fig. 4.1D).

The heating rate at ^{o}C/g/min (Fig. 4.1E) is similar to Fig. 4.1C, although it is slightly less curved. The increase in heating rate (Fig. 4.1F) is not as great above 350^{o}F (191^{o}C) as in Fig. 4.1D, but it clearly increases in an almost linear fashion as well. Judging from the number of contour lines (Fig. 4.1D and Fig. 4.1E) one crosses when one moves horizontally along a given ET, this variable is more a function of CT than of ET as well. The minimum computed value for the plot and surface (Fig. 4.1E and 4.1F) is 0.000083, with a maximum of 0.000228^{o}C/g/min.

The total cooking times of the turkey halves ranged from 72.35 to 238.70 minutes. The contour plot (Fig. 4.2A) and the response surface (Fig. 4.2B, viewpoint three) both indicate that the longest

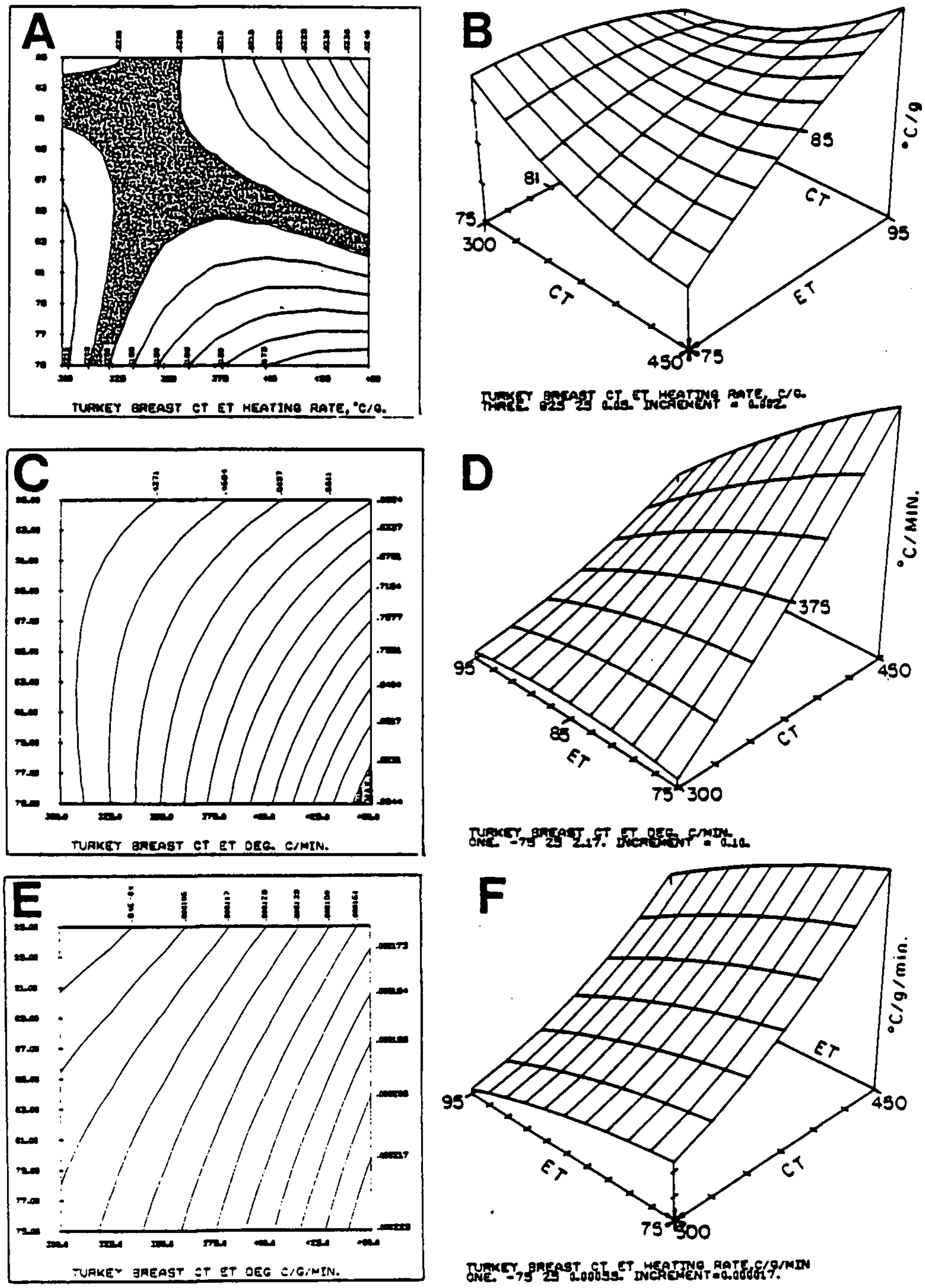


Fig. 4.1. Half-turkey roast contour plots and response surfaces with independent variables, cooking (oven) temperature (CT, X-axis), °F, and endpoint temperature (ET, Y-axis), °C for the response variables (Z-axis), heating rates, °C/gram (A; B), °C/min (C; D) and °C/g/min (E; F).

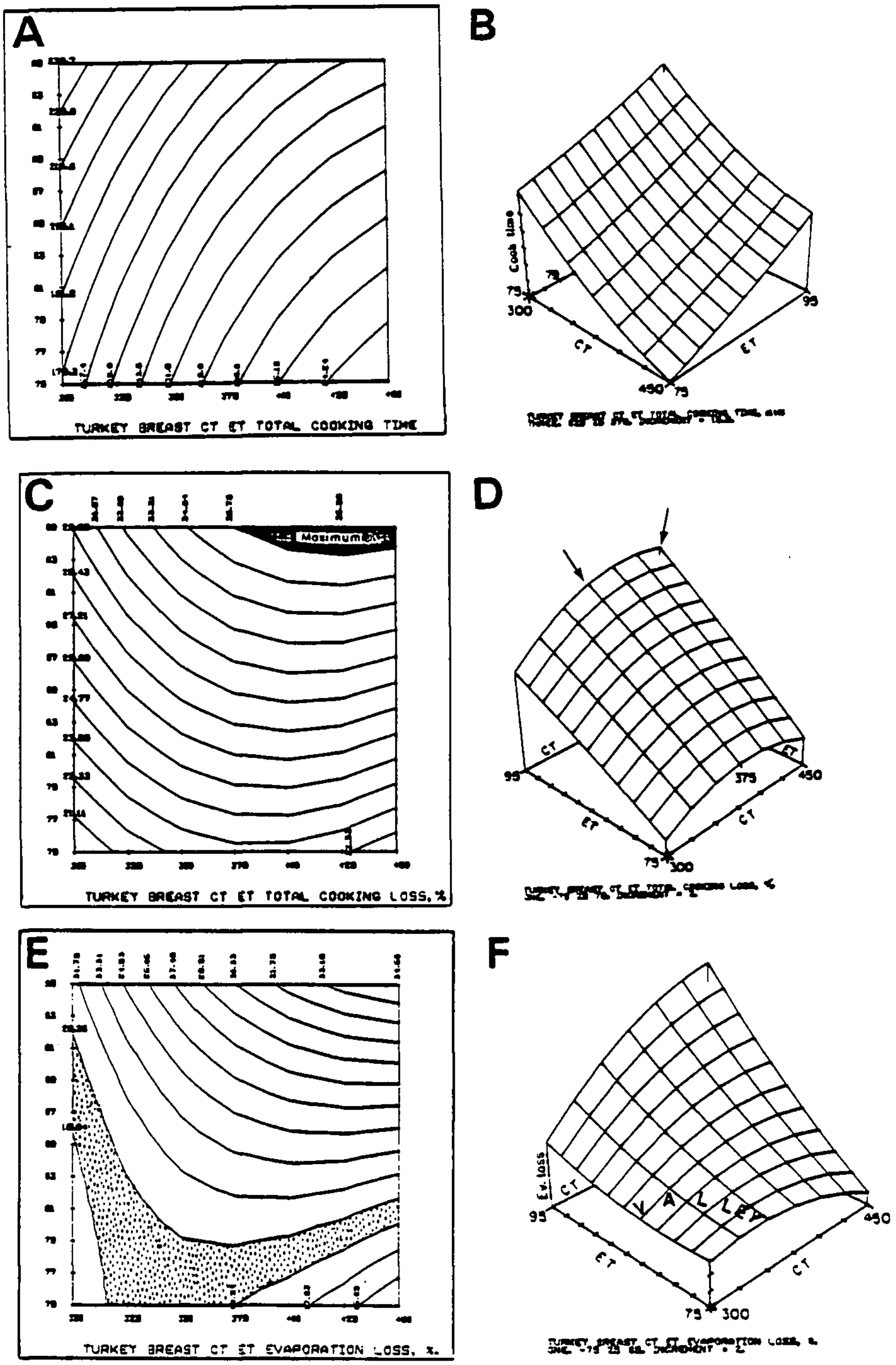


Fig. 4.2. Half-turkey roast contour plots and response surfaces with independent variables, cooking temperature (CT, ^{o}F, X-axis) and endpoint temperature (ET, ^{o}C, Y-axis), for the response variables (Z-axis), cooking time, min (A; B, viewpoint 3), total cooking loss, % (C; D) and evaporation loss, % (E; F).

cooking time comes at the lowest CT (300°F/149°C) and highest ET (95°C) combination, as expected. Similarly, the shortest cooking times fall at the highest CT (450°F/232°C) and the lowest ET (75°C) (Fig. 4.2B, corner nearest viewer). Judging from the contour plot, there is no "optimum" or maximum peak found in this variable. Part of the reason could be due to the fact that the roasts were not of exactly the same initial weight and they are irregularly shaped, with bones extending in most directions. Judging from the number and direction of contour lines, the ET has slightly more of an effect than does CT.

Total cooking loss (%) for roast turkey halves shows plots (Fig. 4.2C-4.2D) where ten contours are crossed along the entire ET range from bottom to top (75 to 95°C), when moving along the 375°F (191°C) line, as opposed to approximately five crossed when moving from low CT to high CT, for example along the 85°C line. This shows that this variable, total cooking loss (%), exerts a greater influence. The response surfaces show the highest cooking losses at the highest ETs, especially above 75°C and especially along a crest (arrow) between 375°F (191°C) and 400°F (204°C) and at the maximum CT-maximum ET corner. This combination of CT-ETs (between 375°F/191°C and 450°F/232°C, at 95°C) came close to the "optimum" or maximum value, as there is a definite peak area present in the maximum CT- maximum ET "corner". High total cooking loss is undesirable as it would mean lower yield and decreased juiciness of the cooked product. In this case, it would be best to avoid these higher ET ranges (at any CT) in order to obtain better yields.

The evaporation cooking loss (%) contour plot (Fig. 4.2E) resembles those for total cooking loss in overall shape, although a partial saddle-region is visible in the low CT-low ET corner (shaded). This region is also shown by the arrows in Fig. 4.2F. The contour plot shows increasing evaporation loss (%) values from minimum to maximum ET, but with a maximum evaporation taking place between about 375°C and 450°F (191 and 232°C). As expected, this occurs mainly around the maximum endpoint temperatures (ETs) of 89-95°C. Thus, the lower CT and ET ranges are preferable for reducing evaporation loss in roast turkey halves, cooked uncovered.

Both the cooking loss (%) plots (Fig. 4.2A and 4.2C) show that the CT-ET combination is approaching a stationary maximum point within a maximum region (shaded areas).

The minimum computed value for total nitrogen (mg N/mg breast meat or %, dry weight basis) retained is 0.1204, with a maximum of 0.1604 mg N/mg breast, dry weight basis. This maximum value falls into an almost-ellipsoid "optimum" area captured partially in the contour plot (Fig. 4.3A, shaded). There is evidence of a hill visible in the response surface (Fig. 4.3B) indicating that maximum total nitrogen retention is found in the high CT-high ET area.

Non-protein nitrogen (NPN) (mg N/mg breast, wet weight basis) was the only wet weight basis protein variable found to be significantly influenced by the CT-ET combinations (Table 4.4). The contour plot (Fig. 4.3C) shows a definite saddle (shaded) between a CT of 300 and 400°F (149 and 204°C) and especially between 75 and 91°C ET. It is shown in the response surface (Fig. 4.3D, arrows) as a more definite valley between 350 and 400°F (177°C and

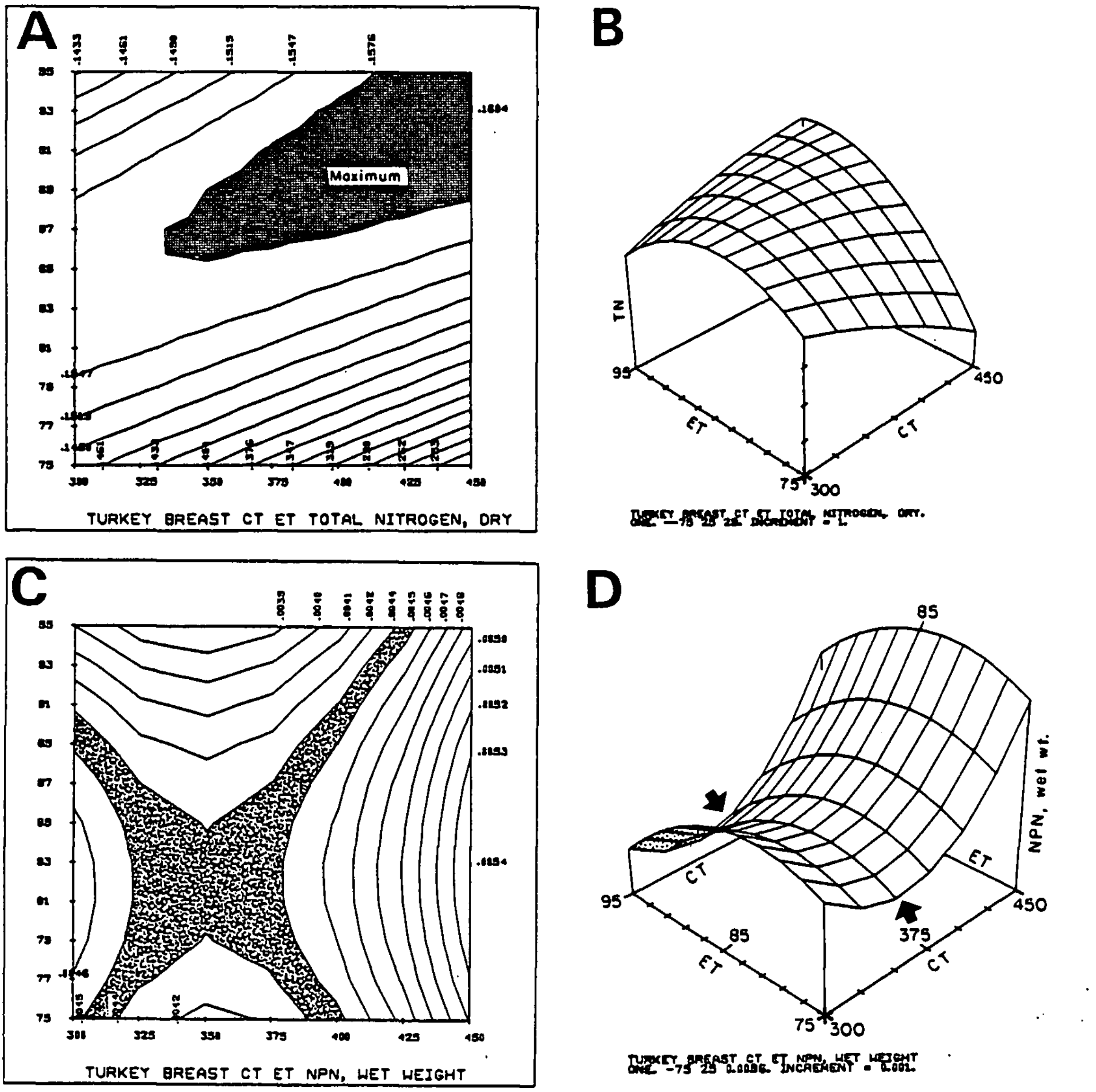


Fig. 4.3. Half-turkey roast contour plots and response surfaces with independent variables, cooking temperature (CT, °F, X-axis) and endpoint temperature (ET, °C, Y-axis), for the response variables (Z-axis), total nitrogen (dry weight) (A; B), NPN protein (wet weight) (C; D).

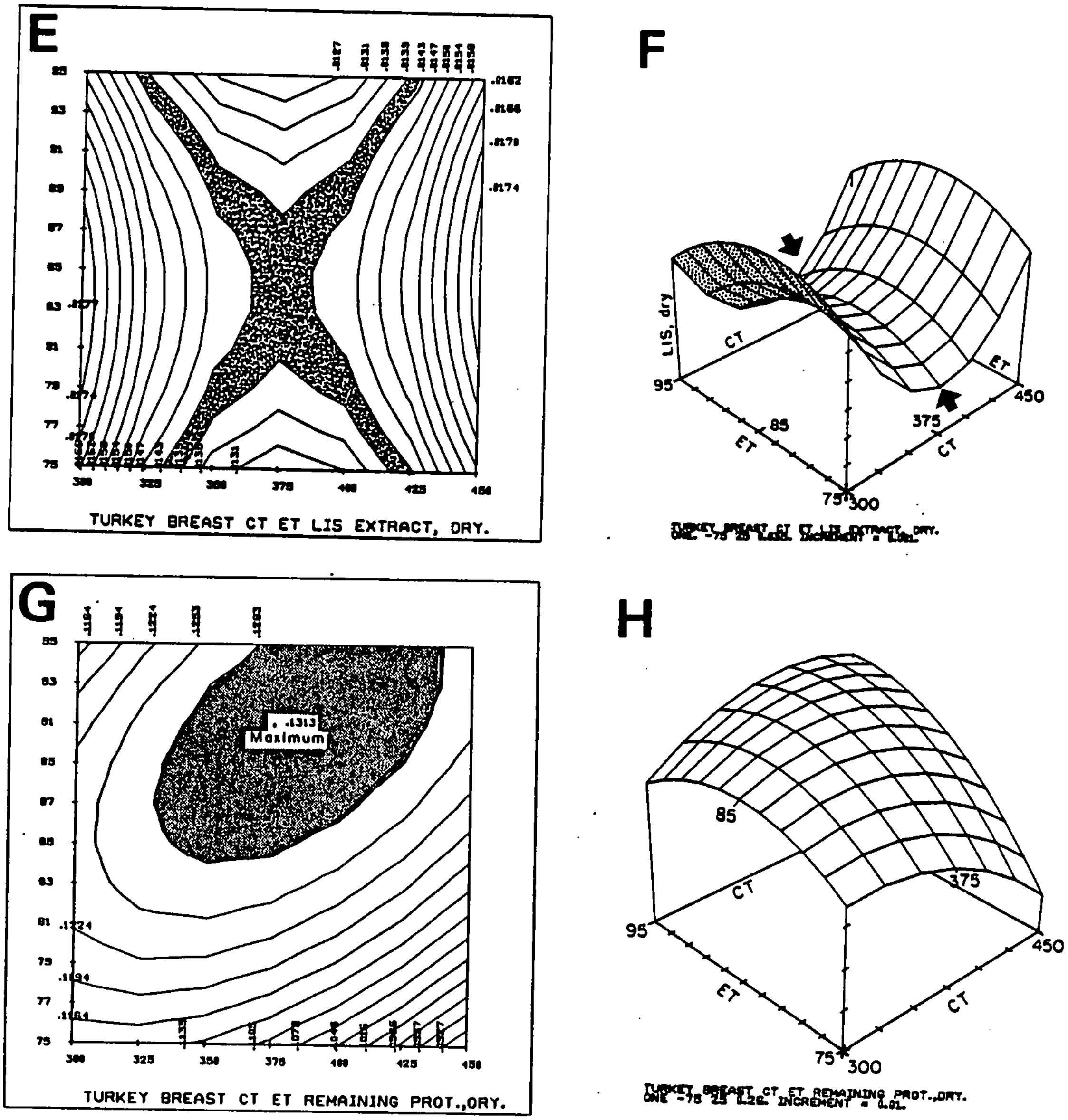


Fig. 4.3. Half-turkey roast contour plots and response surfaces with independent variables, cooking temperature (CT, °F, X-axis) and endpoint temperature (ET, °C, Y-axis), for the response variables (Z-axis), LIS protein (dry weight) (E; F), remaining protein (mg N/mg pork sample, dry weight basis) (G; H).

204°C). The maximum NPN retention range falls along the ET axis, on the 450°F (232°C) CT line. The CCRD center points fall in the valley (Fig. 4.3D), and all along the 350-400°F (177-204°C) CT range. The low NPN retention values roughly coincides with the crest observed in the total cooking loss (%)(Fig. 4.2D, arrow). Evidently, the NPN is related to the total cooking losses. It was surprising not to find a significant ($P\leq0.10$) influence of the CT-ET combinations on drip loss (%). The drip loss data may have been more variable due to trapped fat in adipose tissue. The extractives would have been expected to coincide also with a significant influence of the CT-ET combinations on total moisture of the breast meat. This was not shown either. Further understanding of changes in components in turkey during heating would help clarify these apparent inconsistencies. The saddle observed in the low ionic strength soluble extract (LIS) contour plot (Fig. 4.3E) is similar to the one shown in NPN, wet weight basis (Fig. 4.3C), although it extends over the whole ET range and falls between 163 and 218°C (325 and 425°F).

The remaining protein (mg N/mg breast meat, dry weight basis) contour plot shows that the CT-Et combinations chosen for this experiment cover the ellipsoid "optimum" (maximum) area (Fig. 4.3G, shaded). This maximum peak is on the 375°F/191°C-91°C coordinate - close to the center point values of 375°F (191°C) and 85°C. The response surface does not show a clear peak, as the range in values is only 0.04 mg N/mg breast meat. The minimum corner is in the maximum CT-minimum ET area (Fig. 4.3G and 4.3H). The limited range may be due to the extensive denaturation of the remaining protein at all CT-ET combinations.

According to sensory evaluation data, the only significant quality characteristic variable was thigh meat juiciness (P=0.01). This is perhaps more predictable for the juicier thigh meat as compared to breast meat (Goertz, et al., 1960). Wilkinson and Dawson (1967) found that dark meat was less adversely affected by higher temperatures (for example, 88°C) than breast meat, but that both received most desirable juiciness scores when cooked to an endpoint of 71°C.

Turkey thigh juiciness response surfaces show a linear plane (Fig. 4.4A and 4.4B, viewpoint five), with the higher juiciness scores noticed along all the CTs and ETs, the highest corner being the low CT-low ET one. The shaded maximum CT-minimum ET corner of the contour plot (Fig. 4.4A) of low (dry) values is evident in the response surface (Fig. 4.4B, viewpoint 3, corner nearest viewer). The least-juicy corner (Fig. 4.4B, see arrows) is not the same as the highest cooking time corner (Fig. 4.2B). However, the highest cooking time showed the highest evaporation loss corner (Fig. 4.2B). Usually, one expects decreased juiciness with increased cooking time, but this could be affected by the method of roasting (Cornforth et al., 1982; Wilkinson and Dawson, 1966). Judging from the contour lines (Fig. 4.4A) for thigh juiciness, CT influences juiciness more than ET does.

Predictive ability of the CCRD and quadratic regression model is shown in Table 4.5. The predicted or estimated Y-variable (dependent variable) values are given, using the CKPM control turkey halves and a CT of 350°F (177°C) and an ET of 80°C. When these laboratory-obtained values are compared to the range values of the

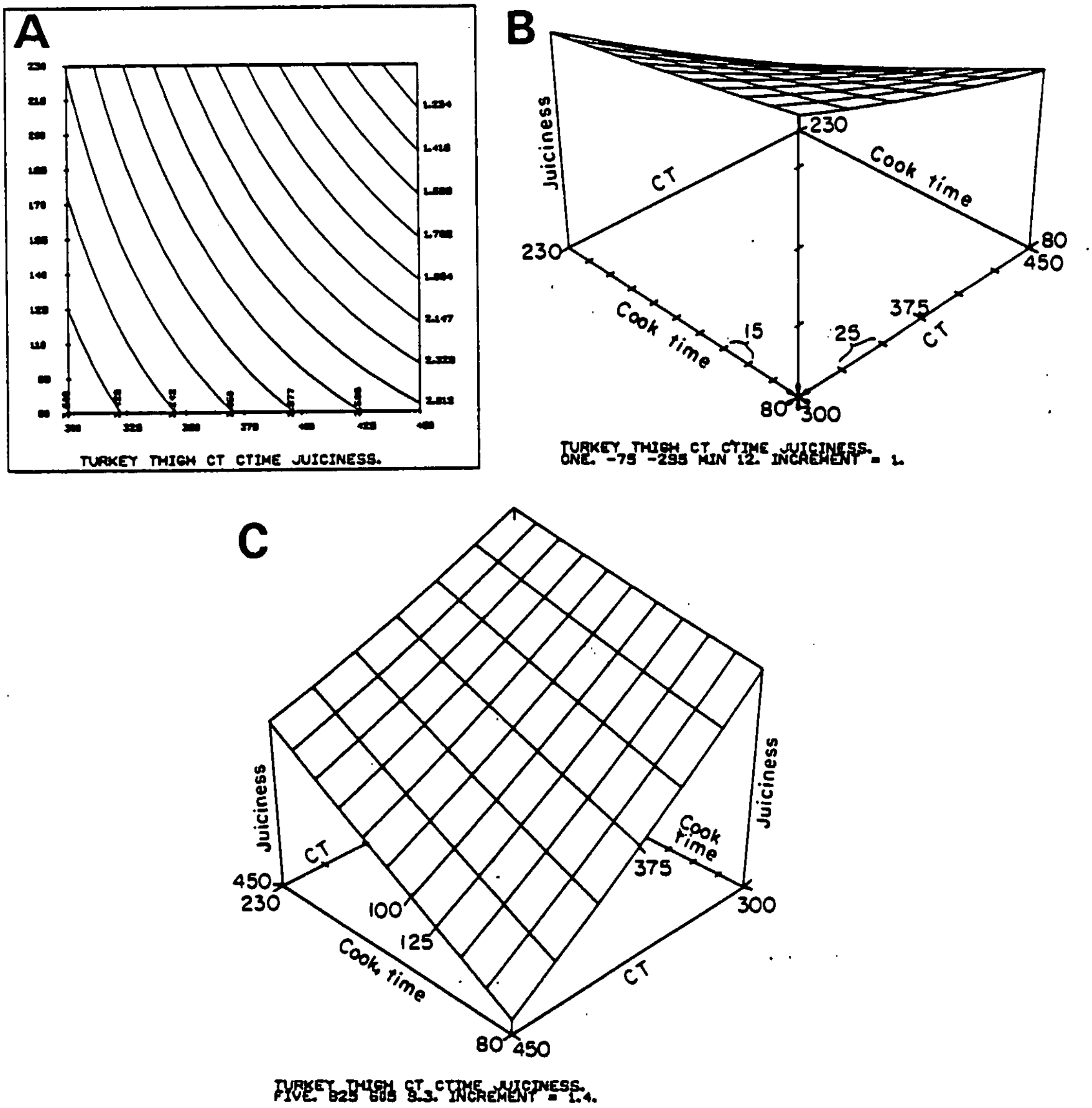


Fig. 4.4. Half-turkey roast contour plot and response surfaces with independent variables, cooking temperature (CT, °F, X-axis) and endpoint temperature (ET, °C, Y-axis), for the thigh juiciness response variable (A; B=viewpoint 5).

contour plot, they should fall within the range (for example, Fig. 4.2C, 4.3A and 4.3A, marked with asterisks) thereby emphasizing another major role of the contour plots in a practical, industrial or institutional setting. From this it can be seen that the ability to predict is accurate, especially for total cooking loss (%), evaporation loss (%), cooking time (min), total nitrogen (mg N/mg breast meat, dry wt basis), heating rate (^{o}C/g) and juiciness. The protein fractions are less accurate, but this is understandable as protein solubility is sensitive to slight differences in thermal stress and/or buffer concentration changes can cause variability in the amounts extracted (Gaska and Regenstein, 1982).

CONCLUSION

In conclusion, this CCRD may be used for predicting the behavior of selected dependent variables in turkey halves roasted at the tested CTs falling between 300 and 450^{o}F (149 and 232^{o}C) and internal ET's ranging from 75 to 95^{o}C. According to the RSA, the lower CT-ET combinations are favored for reduced cooking losses (total and evaporation), whereas the higher CT-ET combinations indicate an increased heating rate (^{o}C/min and ^{o}C/g/min). The effects on protein extracts would appear to visually emphasize the importance of the functionality of turkey breast proteins. Judging from the CKPM experiment, this regression model, its coefficients, and CCRD can predict the significant quality characteristics successfully.

This CCRD, coupled with RSA, is also important for the variables which exhibited non-significance. The lack of a significant influence of the CT-ET combinations upon breast meat sensory characteristics within the range studied minimizes their importance in future cooking considerations. By examining the three-dimensional response surfaces, one obtains immediate insight into the response of the variables to the CT-ET combinations used. The contour plots may be applied directly for rough estimates if one plots the CT (^{o}F) and ET (^{o}C) under investigation on the graph and reads off the approximate contour line or region's value(s). This procedure ensures that one remains within the temperature limits tested.

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Chapter 5

PREDICTION OF CONTROL AND PRERIGOR PRESSURIZED BEEF MEAT QUALITY CHARACTERISTICS AND SOME RELEVANT AMONG-SPECIES COMPARISONS

The three major species reported in the two previous papers were all fed and processed according to standardized, conventional methods. This chapter reports the results of a brief exploratory investigation of how a unique processing method influenced predictability effects of cooking temperature (CT) and endpoint temperature (ET) combinations.

Beef Materials and Methods

Control and prerigor, pressurized (treated) processed beef were used to explore the application of a 2-factor central composite rotatable design (CCRD) and response surface analysis (RSA) to evaluate various "quality-denoting" variables or responses for quality prediction.

The beef samples and the processing procedures are described by Riffero and Holmes (1983). Both prerigor pressurized and conventionally processed samples of the semitendinosus samples were evaluated. Due to the length of the storage period for frozen beef (18 months) and insufficient sample size, no color or sensory tests were done. The cooking temperatures (CT) and endpoint temperatures

(ET) for the CCRD for beef are indicated in Table 5.1. Cooking time and cooking losses (Riffero and Holmes, 1983), total moisture, expressible moisture, and shear values were determined on each roast beef sample. Total protein and remaining protein were determined according to the methods reported in chapter 3.

The nature of the 2-factor CCRD

As with the other three species, the two-factor Central Composite Rotatable Design (CCRD) (Cochran and Cox, 1957) was chosen to allow maximum cooking and internal endpoint temperature coverage with the limited amount of sample available. The cooking temperature (CT) range chosen for beef was 300 to 450°F (149 to 232°C) (with °F customary household oven temperatures used in the design development), and the endpoint temperature (ET) range was from 60 to 90°C (Table 5.1). The description and nature of the two-factor CCRD is identical to that used for the pork CCRD (Chapter 3). As noted in Table 5.1, the nine oven (cooking) temperature-endpoint temperature combinations are given in both °C and °F, with endpoint temperature only in °C. CT-ET combinations were randomly allocated to the beef. The roasted semitendinosus muscle was trimmed and used for the various physical and chemical tests.

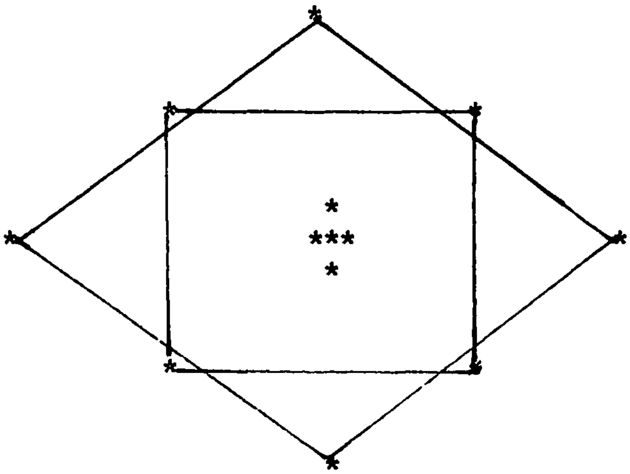
Statistical Analysis

The statistical analysis was done as described in Chapter 3. Single regressions were done on the control beef, whereas double regressions were performed on the treated beef cooking data as the CCRD was replicated.

Table 5.1. Visual display of the control and prerigor, pressurized beef blocks' cooking temperature- endpoint temperature combinations used for this CCRD design with two independent variables. Cooking temperature is given in both °C and °F, with endpoint temperature only in °C.

Design Points	-1.414	-1	0	1	1
Cooking Temperature, °F	300	322	375	428	450
Cooking Temperature, °C	149	161	191	220	232

Design Points	Endpoint Temperature, °C
1.414	90.0
1	85.6
0	75.0
-1	64.4
-1.414	60.0



RESULTS AND DISCUSSION

The significant variables are listed in Table 5.2 and the A-F coefficient values for the significant variables in Table 5.3. All the double regression values cooking data for treated beef is significant ($P \leq 0.10$) except for the drip loss (%), as opposed to the control beef which shows significance for heating rates, $^{o}C/g$ and $^{o}C/g/min$, total cooking loss (%) and evaporation loss. The non-significance of the drop loss values can perhaps be explained by the fact that there was drip loss present in the plastic bags upon defrosting of the raw sample. Control beef is the only species that has not shown significance for cooking time. This might be due to the age of the frozen sample or the nature of the meat itself.

Contour plots and Response Surface Analysis

Selected contour plots and response surfaces are shown, to illustrate influence of the CT-ET combinations. Differences incurred through the processing procedure can also be viewed. The response surface for treated beef total cooking loss (Fig. 5.1C-5.1D) is a linear plane and control beef (Fig. 5.1A-5.1B) is only slightly curved. This is perhaps due to the fact that approximately 90 g blocks were used. Cooking time (Fig. 5.2A-5.2D) shows uniformity in that all the peaks are found in the low CT-high ET corner (arrows). Total moisture (Fig. 5.3A-5.3D) is high in the low CT-low ET ranges and lower in the high CT-high ET areas whereas it is just the opposite for the other species. This probably relates to the shape and size of the blocks, as more evaporation takes place from the proportionally larger

Table 5.2. Within-species and across-species analysis of variance significant variables for frozen control and treated (prerigor pressurized) beef for the two-factor central composite rotatable design (CCRD).

Y-variables	P-values/Significance values Beef Control	 Beef Treated
Heating rate, °C/g	0.02	0.0002
Heating rate, °C/min,	N.S.[a]	0.004
Heating rate, °C/g/min	0.019	0.010
Total cooking loss, %	0.097	0.0001
Drip loss, %	N.S.	N.S.
Evaporation loss, %	0.088	<0.0001
Cooking time, min	N.S.	0.008
Expressible moisture index	0.02	N.S.
Percent total moisture	N.S.	0.008
Total nitrogen and %, wet weight	N.S.	N.S.
Low ionic strength, wet weight	N.S.	N.S.
Non-protein nitrogen, wet weight	N.S.	N.S.
Sarcoplasmic protein fraction, wet weight	N.S.	N.S.
Total nitrogen and %, dry weight	N.S.	N.S.
Low ionic strength, dry weight	N.S.	0.02
Non protein nitrogen, dry weight	N.S.	N.S.
Sarcoplasmic protein fraction, dry weight	N.S.	N.S.

[a] N.S. means "Not Significant" at $P \leq 0.10$ level.

Table 5.3. Quadratic regression model coefficients for beef control and treated.

	A (constant)	B	C	D	E	F
Control						
Expressible moisture index	2.079	- 0.00532	-.0.02451	0.000009983	0.0002862	- 0.00003506
Proteolytic enzyme activity difference, 37 - 0°C	0.5893	- 0.001113	- 0.009682	0.000001667	0.00005662	0.0000002552
Total nitrogen mg N/mg meat wet weight basis	0.0229	- 0.000133	0.001405	0.0000007597	0.000008545	- 0.000006765
Total nitrogen, %	2.29	- 0.0133	0.1405	0.00007597	0.0008545	- 0.0006765
Low ionic strength soluble fraction, mg N/mg meat, wet weight basis	0.01877	0.0001288	- 0.001098	- 0.0000001011	0.000008505	- 0.000000544

Table 5.3. Quadratic regression model coefficients for beef control and treated (continued).

	A (constant)	B	C	D	E	F
<u>Treated</u>						
Total moisture, %	201.4	- 0.2228	- 2.229	0.0001265	0.007496	0.001805
Proteolytic enzyme activity, 0°C	9.771	- 0.01265	- 0.1812	0.000005873	0.0008507	0.0001066
Proteolytic enzyme activity, 37°C	10.44	- 0.0137	- 0.1925	0.000006863	0.0009115	0.0001100
Proteolytic enzyme activity difference, 37 - 0°C	0.667	- 0.001045	- 0.01128	0.0000009905	0.00006087	0.000003438
Low ionic strength soluble fraction, mg N/mg meat, dry weight basis	0.1662	- 0.0002282	- 0.002656	0.00000003582	0.000009408	0.000002481

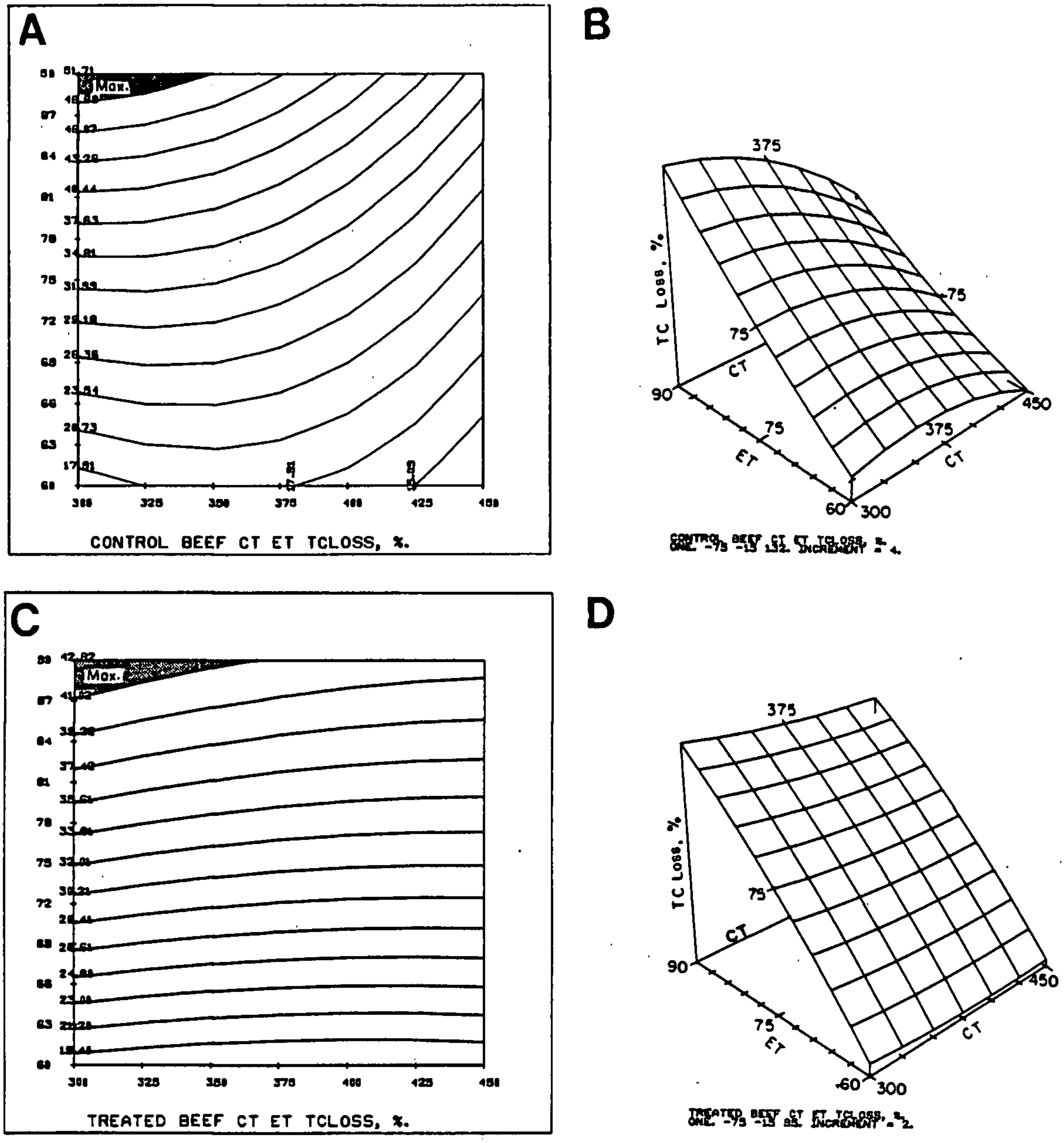


Fig. 5.1. Between species contour plots and response surfaces with independent variables, cooking (oven) temperature (CT, X-axis), °F, and endpoint temperature (ET, Y-axis), °C for the response variables (Z-axis), total cooking loss, % for control beef (A; B) and treated beef (C; D).

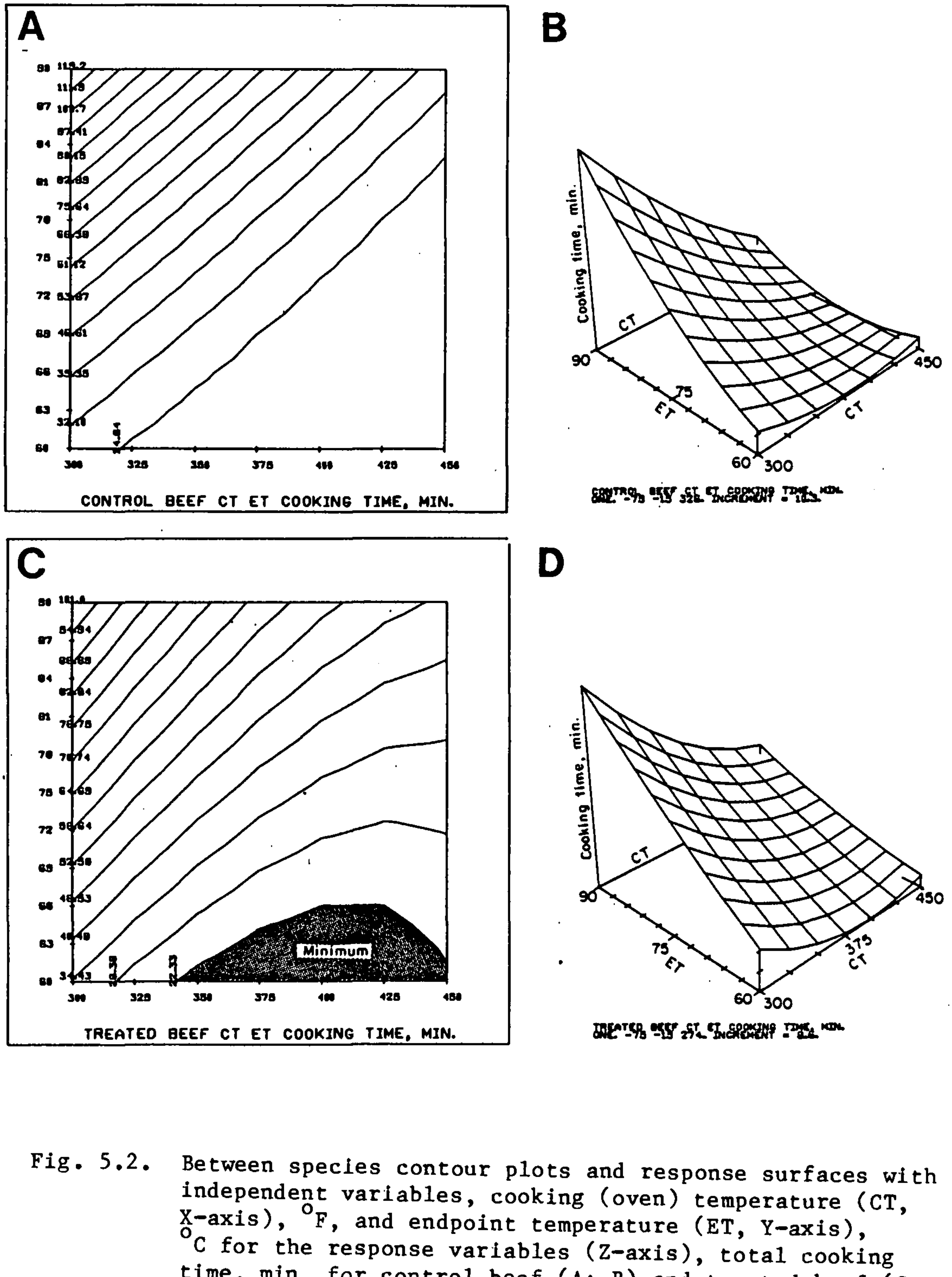


Fig. 5.2. Between species contour plots and response surfaces with independent variables, cooking (oven) temperature (CT, X-axis), °F, and endpoint temperature (ET, Y-axis), °C for the response variables (Z-axis), total cooking time, min, for control beef (A; B) and treated beef (C; D).

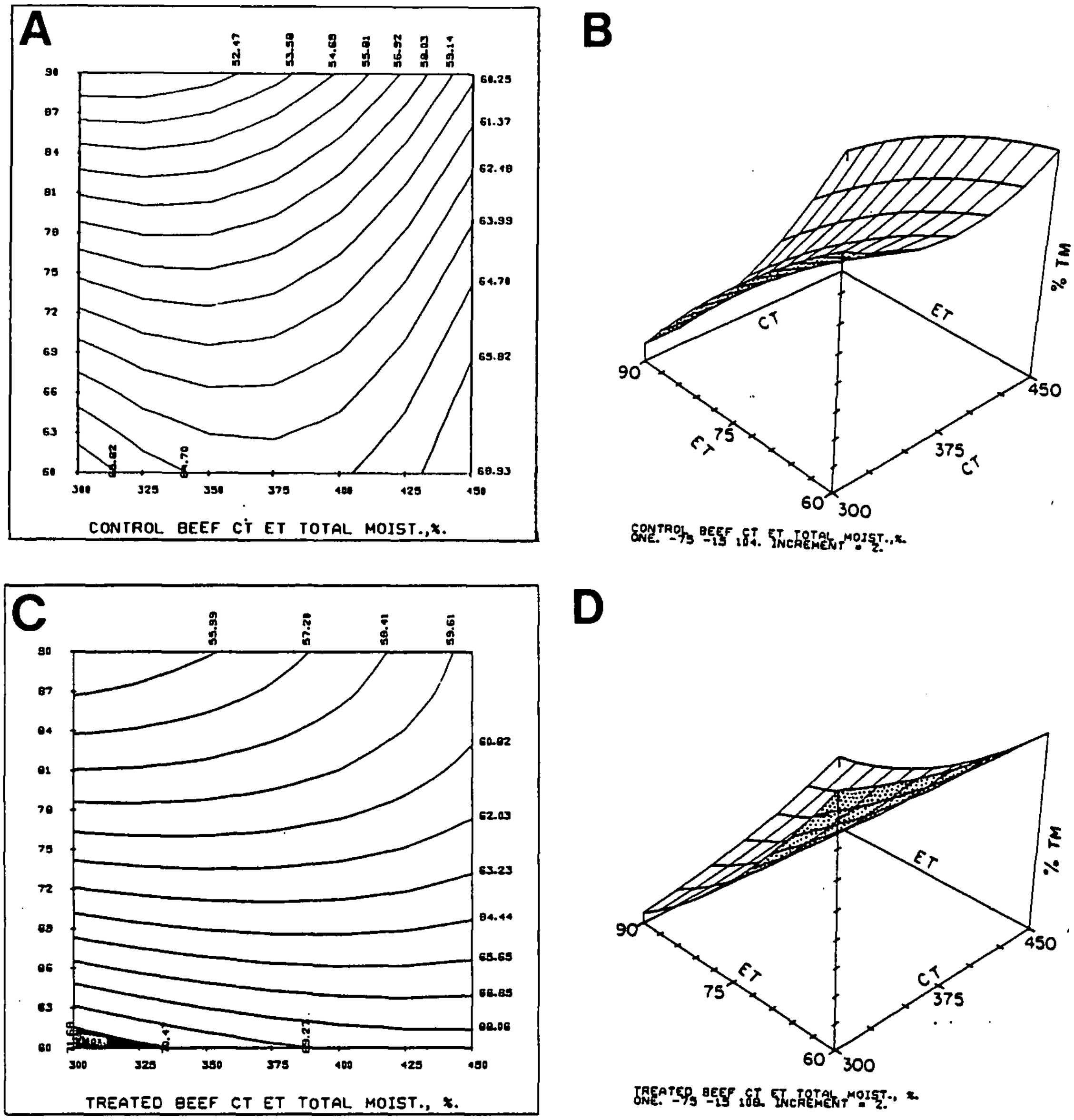


Fig. 5.3. Between species contour plots and response surfaces with independent variables, cooking (oven) temperature (CT, X-axis), °F, and endpoint temperature (ET, Y-axis), °C for the response variables (Z-axis), total moisture, % for control beef (A; B) and treated beef (C; D).

unit surface area of the smaller beef blocks as compared to the pork or lamb loin roasts. The Warner-Bratzler tenderness contour plot and response surface (Fig. 5.4A-5.4B) for treated beef show a twisted saddle. (No data were collected for control beef.) This twisted saddle is probably due to an interaction of time and temperature on the prerigor pressurized (PRP) treated myofibrillar and connective tissue. The EMI contour plots indicate a differing influence of the CT-ET combinations on water-holding capacity. There is a max region captured in the control beef EMI contour plot (Fig. 5.3C) whereas the treated beef exhibits a saddle (Fig. 5.4E). Again, this may visually emphasize the effect of PRP on the myofibrillar protein.

The low ionic strength extract, dry weight basis, for treated beef is significant at P=0.02 and contour plots for both control (Fig. 5.5A) and treated beef (Fig. 5.5C) are shown, for comparison, to indicate the marked difference in the depth of the treated beef valley as opposed to that of the control beef. The minimum circular region is visible in the 70 to 85°C region of the control beef (Fig. 5.4A) whereas it appears to be in the 87+°C corner of the treated beef (Fig. 5.4C). The low ionic strength extract was defined by Hegarty et al. (1963) as the fraction soluble in a potassium phosphate buffer of ionic strength 0.05 and at pH 7.6. These figures (Fig. 5.4) emphasize that PRP treatment influenced proteins in a unique manner.

CONCLUSION

The different types of responses (troughs, saddles and linear

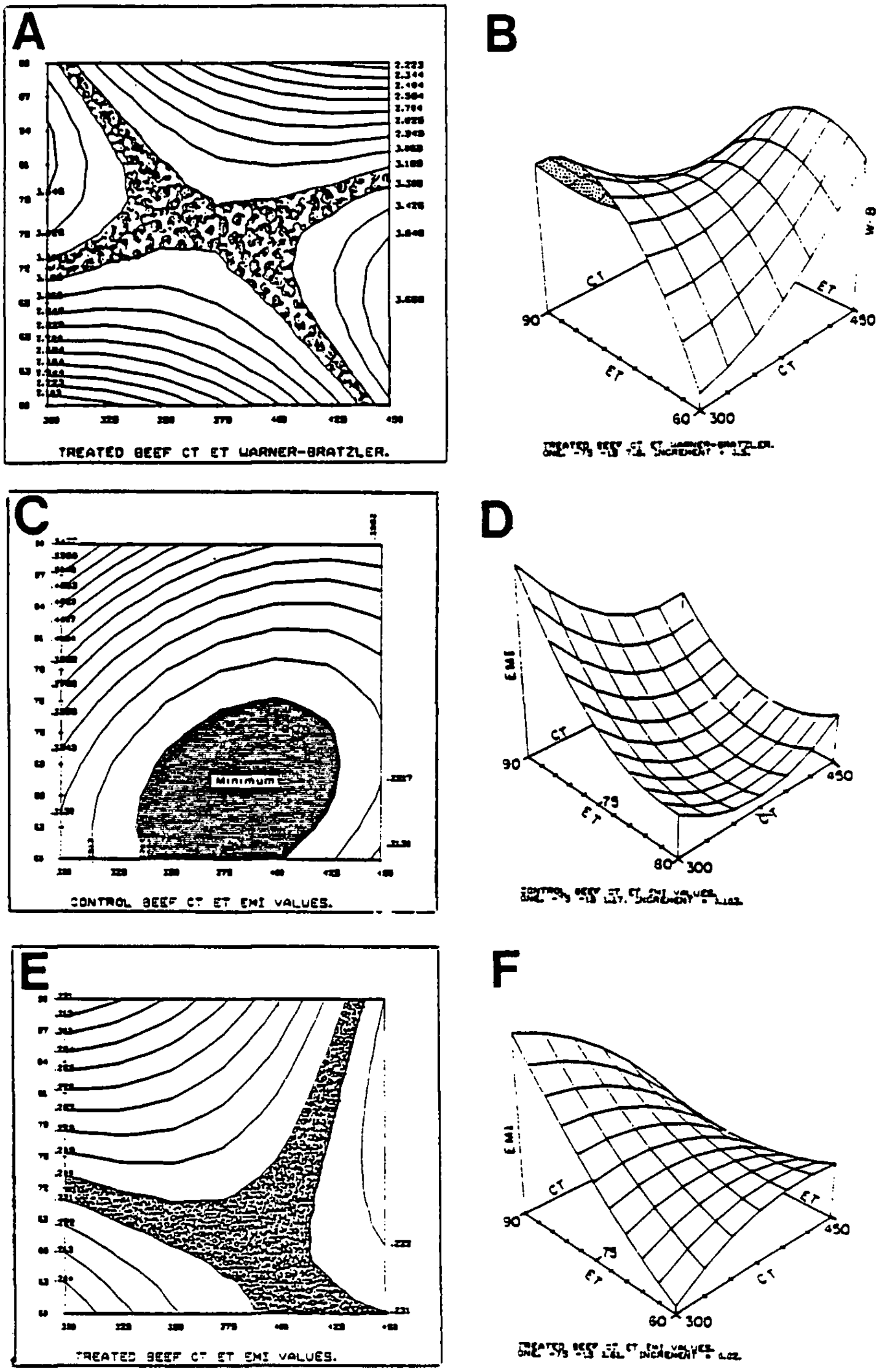


Fig. 5.4. Between species contour plots and response surfaces with independent variables, cooking (oven) temperature (CT, X-axis), °F, and endpoint temperature (ET, Y-axis), °C for the response variables (Z-axis), for Warner-Bratzler for treated beef (A=saddle, shaded; B) and EMI values for control beef (C=minimum region, shaded; D), and treated beef (E=saddle, shaded; F).

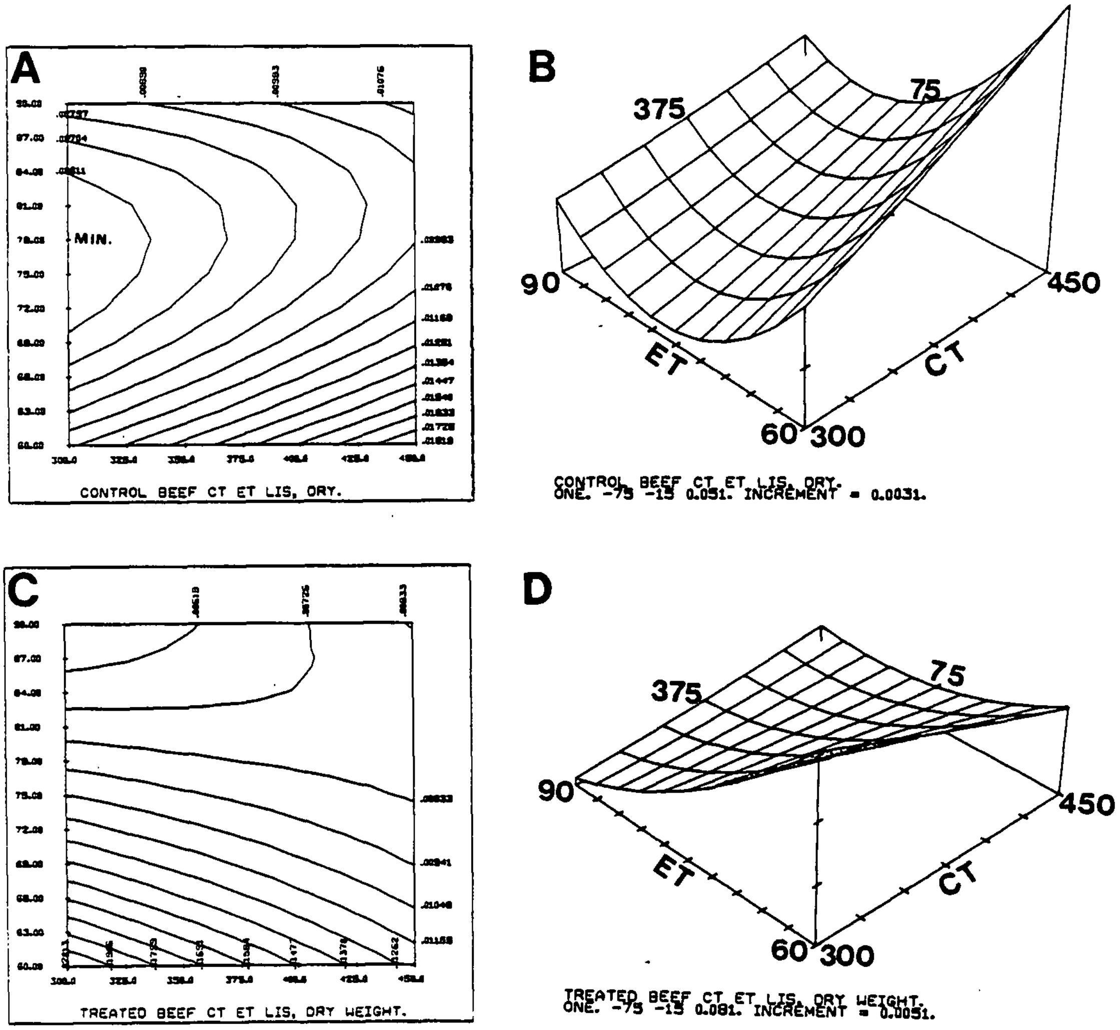


Fig. 5.5. Between species contour plots and response surfaces with independent variables, cooking (oven) temperature (CT, X-axis), °F, and endpoint temperature (ET, Y-axis), °C for the response variables (Z-axis), low ionic strength extract, dry weight basis, for control beef (A=shaded, minimum region; B=valley, arrow) and treated beef (C=shaded, minimum region and partial saddles; D).

planes) found in the beef emphasize the complexity of meat, their muscle systems and their individual responses to heat treatments and other processing and handling variables. It is apparent that there are differences between the control and treated beef; that prerigor, pressurized treatment of the beef did make a difference, even when measured after a long frozen-storage period. The CCRD model is a valid predictor when testing the CT-ET effects. In this particular case, the model and contour plots and response surfaces visually emphasized some unique qualities of treated samples that have not been noted before.

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Chapter 6

FUTURE RESEARCH

The analysis and evaluation of the data collected in the laboratory have both shown the potential of the central composite rotatable design and response surface analysis. Select variables were determined to be influenced by the CT-ET combinations used for pork, lamb, turkey and beef. These significant results usually followed generally accepted "truisms". Additionally, the analyses permitted the visual emphasis of the various heating relationships on the selected meats from the species under study. It was possible to evaluate their behavior under various heating conditions and their resulting effect upon meat quality. This could prove beneficial in future work where one is interested in discovering more about underlying mechanisms or physical and chemical attributes.

From the data analyzed in this study, it is apparent that the anomalies in relationships of various quality characteristics as affected by cooking temperature and endpoint temperature can be determined. This particular statistical design and response surface analysis procedure could be used to effectively focus microstructural and molecular research towards areas where there is an incomplete understanding of product reactions or factors towards ingredient optimization.

Of particular interest for future research is the increased effectiveness of the double regressions over the single regressions and the determination of the number of center point replications one would have to have. One of the advantages of the CCRD design is its capability to encompass a large number of treatments with a minimum of replications, preferably with not more than three independent variables. Thus, the results from the current experiment would direct future planning toward determining the "best" effective minimum number of replications. In any case, the CCRD in conjunction with response surface analysis permits not only the determination of the relationships of independent variables to dependent variables, but, it will predict the results of treatments as long as they are within the limits of experimental independent variables.

Chapter 7

SUMMARY

A two-factor Central Composite Rotatable Design (CCRD) was applied to pork, lamb, turkey breast and thighs, and control and treated semitendinosus beef blocks. The two factors (independent variables) used were cooking temperature (CT, in °F) and endpoint temperature (ET, in °C).

The dependent variables were physical and chemical objective tests, including cooking losses (total, drip and evaporation, %), heating rates (°C/g, °C/min, °C/g/min), cooking time, total moisture, expressible moisture index, Warner-Bratzler tenderness, total nitrogen, various protein extractions (including low ionic strength, non-protein nitrogen, remaining protein extract, wet and dry weight basis), Photovolt color data and its transformations, and sensory evaluation (tenderness, flavor, doneness, juiciness and color).

The quadratic regression model used was:

$$\hat{y} = Y\text{-hat} = A + B*CT + C*ET + D*CT*CT + E*ET*ET + F*CT*ET$$

The CCRD CT range for all the species studied was from 350 to 450°F (149 to 232°C), whereas the ET varied according to the species concerned, with lamb and beef from 60 to 90°C and pork and turkey from 75 to 95°C. For each species the nine CT-ET combinations were calculated with five center point replications.

This meant 13 observations per species and for turkey, lamb and treated beef, the design was replicated twice.

Warner-Bratzler shear values were obtained using the method described by Riffero and Holmes (1983), total moisture according to the AOAC (1980) method, water holding capacity (EMIs) according to Wierbicki and Deatherage (1958), total nitrogen using the AOAC (1980) micro-Kjeldahl method, protein extractions according to Hegarty et al. (1963) and Holmes (1972) and color using a Photovolt difference meter with amber, blue and green filters. Sensory evaluation was with a trained panel of Oregon State University staff members, with color being evaluated for pork and lamb only.

Statistical evaluation included regression (Statistical Interactive Programming Package, SIPS, Rowe and Brenne, 1982) and analysis of variance. The response surface analysis consisted of evaluating the two-dimensional contour plots and three-dimensional response surfaces, generated by the specially-developed SURCONN plotting/graphics routines (Fuhrer, 1984), using the regression coefficients and initially viewing all possible variables, not only the significant ones.

The CCRD was found to be successful in its ability to predict significant dependant quality variables and this ability was further tested and confirmed on the turkey experiment results, using a set of six control turkeys cooked at 350°F (177°C) to 80°C. The response surface analysis technique was useful in evaluating the central composite rotatable design as well as the reactions of the individual dependent variables to the CT-ET combinations.

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APPENDICES

Proteolytic Enzyme and pH Tests

The following lists, data files and analysis of variance tables make reference to proteolytic enzyme information at 0°C, 37°C and (37-0)°C, as well as to the pH of the slurry and after enzyme removal. The information is included here as it was also originally included in the Central Composite Rotatable Design (CCRD) as Y-variables. Therefore, it forms an integral part of the computer programs and files. The tests were based on the work reported by Kronman et al. (1960), Laakkonen et al. (1970a and b). Fifteen grams of meat in 75 mL redistilled water was used, and the pH of the slurry before and after enzyme removal was taken at 4°C. The results were not suitable for reporting.

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APPENDIX A

Independent and Dependent Variable Data

Table A.1. Listing of Independent and Dependent Variables

Table A.2. Analysis of Variance of Independent and Dependent Variables for All Meat Species

Table A.1. Independent (X-) and dependent or response (Y-) variables used for the Central Composite Rotatable Design (CCRD) as applied to four meat species, namely beef, lamb, turkey (breast and thigh) and pork.

Independent (temperature) variables

X_1 = Cooking (oven) temperature, ^{o}F. (For response surface analysis, this fell on the traditional, horizontal X-axis.)

X_2 = Endpoint temperature, ^{o}C, taken with thermocouple in geometric center of meat sample. (For response surface analysis, this fell on the traditional, vertical Y-axis.)

Dependent ("response") variables

(For response surface analysis, these Y-variables were represented by the third-dimensional Z-axis or the "height of the surface". The order in which these variables appear here, is different from their order in the computer files, as they are more logically grouped together.)

Cooking data variables

"STRAW" computer files

Y_1 = Initial weight (g). (Used as a "dummy variable" to check on regression and analysis of variance results.)

Y_2 = Heating rate (^{o}C/g).

Y_3 = Heating rate (^{o}C/min).

Y_4 = Heating rate (^{o}C/g/min).

Y_5 = Cooking loss (total cooking loss, %).

Y_6 = Cooking loss (drip loss, %).

Y_7 = Cooking loss (evaporation loss, %).

Y_8 = Cooking time (min).

Table A.1. Independent (X-) and dependent or response (Y-) variables used for the Central Composite Rotatable Design (CCRD) as applied to four meat species, namely beef, lamb, turkey (breast and thigh) and pork (continued).

Moisture, proteolytic enzyme and pH values

"PHENZ" computer files

Y_9 = Expressible moisture index (EMI).

Y_{10} = Percent total moisture (% TM).

Y_{11} = Proteolytic enzyme activity (at 0 ^{o}C).

Y_{12} = Proteolytic enzyme activity (at 37 ^{o}C).

Y_{13} = Proteolytic enzyme activity difference [(37 - 0) ^{o}C].

Y_{14} = pH of meat and redistilled water slurry.

Y_{15} = pH of extract, after enzyme removal.

Y_{16} = Warner-Bratzler shear values (kg/1.27 cm core).

Y_{17} = Enzyme weight (g). (Used as a "dummy" variable to check on regression and analysis of variance results.)

Total nitrogen and protein solubility results: Total nitrogen (TN/mg meat), percent TN, low ionic strength (LIS) soluble protein extract, non-protein nitrogen (NPN) extract, "sarcoplasmic" protein fraction and "remaining" protein fraction (all mg N/mg meat).

"TCAWD" computer files

Y_{18} = Total nitrogen (mg TN/mg meat, wet weight basis).

Y_{19} = Total nitrogen (% TN, wet weight basis).

Y_{20} = Low ionic strength (LIS) soluble protein fraction (mg N/mg meat).

Y_{21} = Non-protein nitrogen (NPN) extract (mg N/mg meat, wet weight basis).

Y_{22} = "Sarcoplasmic" protein fraction [(LIS - NPN) mg N/mg meat, wet weight basis].

Table A.1. Independent (X-) and dependent or response (Y-) variables used for the Central Composite Rotatable Design (CCRD) as applied to four meat species, namely beef, lamb, turkey (breast and thigh) and pork (continued).

"TCAWD" computer files (continued)

Y_{23} = "Remaining" protein fraction [TN - (LIS + NPN) mg N/mg meat, wet weight basis].

Y_{24} = Total nitrogen (mg TN/mg meat, dry weight basis).

Y_{25} = Total nitrogen (% TN, dry weight basis).

Y_{26} = Low ionic strength (LIS) soluble protein fraction (mg N/mg meat, dry weight basis).

Y_{27} = Non-protein nitrogen (NPN) extract (mg N/mg meat, dry weight basis).

Y_{28} = "Sarcoplasmic" protein fraction [(LIS - NPN) mg N/mg meat, dry weight basis].

Y_{29} = "Remaining" protein fraction [TN - (LIS + NPN) mg N/mg meat, dry weight basis].

Color for lamb and pork

"COLOR" computer file

Y_{30} = Photovolt filter, amber.

Y_{31} = Photovolt filter, blue.

Y_{32} = Photovolt filter, green.

Y_{33} = C.I.E. X-value.

Y_{34} = C.I.E. Y-value.

Y_{35} = C.I.E. Z-value.

Y_{36} = Chromaticity coordinate, x.

Y_{37} = Chromaticity coordinate, y.

Y_{38} = Chromaticity coordinate, z.

Table A.1. Independent (X-) and dependent or response (Y-) variables used for the Central Composite Rotatable Design (CCRD) as applied to four meat species, namely beef, lamb, turkey (breast and thigh) and pork (continued).

<u>"COLOR" computer file</u> (continued)

Y_{39} = Hunter L-value.

Y_{40} = Hunter a_L-value.

Y_{41} = Hunter b_L-value.

Y_{42} = Hue angle (tan b_L/a_L).

Y_{43} = Saturation index ($\sqrt{a_L \text{ squared} + b_L \text{ squared}}$).

Sensory Evaluation for Lamb

"CCRDSE3" computer file

Y_{44} = Tenderness (1 = very tough; 5 = very tender).

Y_{45} = Flavor (1 = no meaty flavor; 5 = very pronounced meaty flavor).

Y_{46} = Doneness (1 = very undercooked; 5 = very overcooked).

Y_{47} = Juiciness (1 = very dry; 5 = very juicy).

Y_{48} = Color (1 = rosy red; 5 = brownish grey).

Sensory evaluation for Turkey Breast and Thigh

"CCRDSE4" and "CCRDSE5" on computer file

Y_{30} = Tenderness (1 = very tough; 5 = very tender).

Y_{31} = Flavor (1 = no meaty flavor; 5 = very pronounced meaty flavor).

Y_{32} = Doneness (1 = very undercooked; 5 = very overcooked).

Y_{33} = Juiciness (1 = very dry; 5 = very juicy).

Table A.1. Independent (X-) and dependent or response (Y-) variables used for the Central Composite Rotatable Design (CCRD) as applied to four meat species, namely beef, lamb, turkey (breast and thigh) and pork (continued).

Sensory evaluation for Pork

"CCRDSE6" on computer file

Y_{44} = Tenderness (1 = very tough; 5 = very tender).

Y_{45} = Flavor (1 = no meaty flavor; 5 = very pronounced meaty flavor).

Y_{46} = Doneness (1 = very undercooked; 5 = very overcooked).

Y_{47} = Juiciness (1 = very dry; 5 = very juicy).

Y_{48} = Color (1 = rosy pink; 5 = grey brown).

Table A.2. Within-species and across-species analysis of variance significant variables for fresh pork loin, frozen lamb loin, frozen half-turkeys and frozen control and treated (prerigor pressurized) beef for the two-factor central composite rotatable design (CCRD).

	P-values/Significance values					
Y-variables	Pork	Lamb	Turkey breast	Turkey thigh	Beef control	Beef treated
STRAW[d]						
Heating rate, °C/g	N.S.[a]	0.0764	0.0567	-[b]	0.0234[c]	0.0002
Heating rate, °C/min,	0.095	0.0741	0.0056	-	(0.2605)	0.0048
Heating rate, °C/g/min	(0.139)	N.S.	0.0001	-	0.0188	0.0100
T. Cook loss, %	0.108	<0.0001	0.0899	-	0.0967	0.0001
Drip loss, %	N.S.	0.0002	0.2484	-	N.S.	(0.3643)
Evaporation loss, %	0.078	<0.0001	0.025	-	0.0883	<0.0001
Cooking time, min	0.037	0.0086	<0.0001	-	0.2816	0.0005
PHENZ						
EMT	N.S.	0.0278	N.S.	0.1763	0.0204	(0.2737)
%TM	0.046	0.0704	N.S.	N.S.	N.S.	0.0085
Proteolytic enzyme activity						
at 0°C	0.0001	0.1489	(0.182)	N.S.	N.S.	0.0566
at 37°C	0.14	0.1525	N.S.	N.S.	N.S.	0.0529
(37-0)°C	N.S.	N.S.	N.S.	N.S.	N.S.	0.0012
TCAWD						
Total nitrogen, mg N/mg meat and %, wet weight	N.S.	0.0562	N.S.	N.S.	(0.1851)	N.S.
LIS, wet weight	N.S.	0.151	N.S.	N.S.	N.S.	(0.1019)
NPN, wet weight	N.S.	(N.S.)	0.013	N.S.	N.S.	N.S.
Sarcoplasmic, wet wt.	N.S.	N.S.	0.1175	N.S.	(0.1213)	N.S.
Total nitrogen, mg N/mg meat, and %TN, dry weight	0.0008	N.S.	0.064	N.S.	N.S.	N.S.
LIS, dry weight	N.S.	0.1983	0.022	N.S.	N.S.	0.0174
NPN, dry weight	N.S.	N.S.	(0.123)	N.S.	N.S.	N.S.
Sarcoplasmic, dry	N.S.	N.S.	N.S.	N.S.	(0.1322)	0.0174
Remaining protein fractions, mg N/mg meat, dry	0.0007	N.S.	0.05	N.S.	N.S.	N.S.

Table A.2. Within-species and across-species analysis of variance significant variables for fresh pork loin, frozen lamb loin, frozen half-turkeys and frozen control and treated (prerigor pressurized) beef for the two-factor central composite rotatable design (CCRD) (continued).

	P-values/Significance values					
Y-variables	Pork	Lamb	Turkey breast	Turkey thigh	Beef control	Beef treated
COLOR						
Amber filter	N.S.	(0.1091)	-	-	-	-
Chromaticity coordinate, x	N.S.	0.0071	-	-	-	-
Chromaticity coordinate, z,	0.0348	0.0024	-	-	-	-
Hunter, a_L	N.S.	(0.1528)	-	-	-	-
Saturation index	N.S.	0.084	-	-	-	-
SENSORY EVALUATION						
Tenderness	N.S.	N.S.	N.S.	N.S.	-	-
Flavor	N.S.	(0.1104)	N.S.	N.S.	-	-
Doneness	N.S.	0.006	N.S.	N.S.	-	-
Juiciness	0.1009	(0.1134)	N.S.	0.009	-	-
Color	N.S.	0.0792	-	-	-	-

[a] N.S. means "Not Significant"
[b] - means "Not Done"
[c] ( ) means "close to P=0.10"
[d] Single regressions were done on the "STRAW" data file (cooking loss data, cooking times and heating rates) for pork versus double regressions on lamb and turkey. There is more significance shown in the double sets than in the single and this might be due to species differences, but it might also have to do with the strengthened, reinforced double design, with 25-26 observations versus the single design's 13.

APPENDIX B

Significant Data Tables for Meat Species

Table B.1. - B.5. Significant Data Tables for Pork Loin Roast

Table B.6. - B.10. Significant Data Tables for Lamb Loin Roast

Table B.11. - B.15. Significant Data Tables for Turkey Breast Roast and Turkey Thigh Roast

Table B.1. Data used for regression for variables with significant values according to the ANOVAs of pork loin roast for cooking temperatures, heating rate, and cooking loss.

Code/CCRD Number* n = 14	Cooking Temp. (°F)	Desired Endpoint Temp. (°C)	Actual Endpoint Temp. (°C)	Heating Rate (°C/min)	Total Cooking Loss (%)	Evaporation Cooking Loss (%)	Cooking Time (min)
282	428	79.6	79.9	0.70	31.99	19.23	109.75
349	450	86.0	85.9	0.99	25.93	19.70	83.51
397	322	79.6	79.6	0.51	21.30	16.57	151.50
496	428	92.3	92.3	0.74	30.37	23.50	121.60
652	300	86.0	86.0	0.43	24.80	19.56	193.50
668	375	95.0	75.9	0.54	27.99	20.65	133.75
810	375	77.0	77.0	0.67	22.81	17.37	110.00
866 R	375	95.0	95.0	0.85	34.67	29.45	110.00
919	322	92.3	92.2	0.40	29.46	22.63	224.50
544 1	375	86.0	86.1	0.58	32.53	26.38	142.50
614 2	375	86.0	86.6	0.74	26.62	20.55	113.30
843 3	375	86.0	85.9	0.58	34.38	24.17	144.00
033 4	375	86.0	85.9	0.51	31.17	25.91	162.50
129 5	375	85.0	85.0	0.79	26.30	17.97	103.25

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*Refers to n = 14 not n = 13.

Table B.2. Data used for regression for variables with significant values according to the ANOVA's of pork loin roast for cooking temperatures, and moisture.

Code/CCRD Number n=14	Cooking Temp. (°F)	Endpoint Temp. (°C)	Expressible Moisture Index (EMI)	Percent Total Moisture (% TM)	Juiciness[1]	Warner-Bratzler Shear Values[2]
282	428	79.9	.239	61.41	2.90	4.000
349	450	85.9	.325	59.85	2.00	4.875
397	322	79.6	.272	64.82	3.00	6.775
496	428	92.3	.229	65.28	2.90	3.875
652	300	86.0	.340	63.13	2.90	5.150
668	375	75.9	.296	64.63	3.60	9.500
866 R	375	95.0	.206	66.50	—	4.150
810	375	77.0	.298	59.41	4.10	4.300
919	322	92.0	.337	55.65	2.80	5.525
544 1	375	86.1	.283	63.61	3.00	3.000
614 2	375	86.6	.292	60.26	3.00	4.050
843 3	375	85.9	.293	59.55	2.60	4.625
033 4	375	85.9	.325	59.62	2.20	4.575
129 5	375	85.0	.245	63.44	3.20	3.875

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[1] Juiciness (1 = very dry, 5 = very juicy)

[2] kg/127 mm diameter core.

Table B.3. Data used for regression for variables with significant values according to the ANOVA's of pork loin roast for cooking temperatures, total nitrogen of dry weight basis, and "remaining" protein fraction of dry weight basis

Code/CCRD Number n=14	Cooking Temp. (°F)	Endpoint Temp. (°C)	Total Nitrogen (mg N/mg pork)[1]	"Remaining" Protein Fraction (mg N/mg pork)[1,2]
282	428	79.9	.126086	.112360
349	450	85.9	.128972	.115313
397	322	79.6	.139947	.122708
496	428	92.3	.134610	.124899
652	300	86.0	.121716	.105787
668	375	75.9	.138654	.120883
810	375	77.0	.134337	.117307
866 R	375	95.0	.127525	.113532
919	322	92.0	.102054	.090790
544 1	375	86.1	.115086	.102234
614 2	375	86.6	.123218	.108701
843 3	375	85.9	.120447	.110366
033 4	375	85.9	.122884	.112206
129 5	375	85.0	.125384	.110770

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[1] dry weight basis

[2] Total nitrogen - low ionic strength protein solubility extract + non-protein nitrogen extract (TN - (LIS + NPN))

Table B.4. Data used for regression for variables with significant values according to the ANOVA's of pork loin roast for cooking temperatures, and chromaticity coordinate values for x, y, and z.

Code/CCRD Number n=13	Cooking Temp. (°F)	Endpoint Temp. (°C)	Chromaticity Coordinate x	Chromaticity Coordinate y	Chromaticity Coordinate z
282	428	79.9	.330	.346	.324
349	450	85.9	.323	.343	.334
397	322	79.6	.331	.344	.324
496	428	92.3	.332	.346	.322
652	300	86.0	.328	.344	.328
668	375	75.9	.337	.346	.318
810	375	77.0	.325	.365	.310
919	322	92.0	.331	.351	.318
544 1	375	86.1	.329	.345	.325
614 2	375	86.6	.334	.344	.322
843 3	375	85.9	.324	.346	.330
033 4	375	85.9	.333	.344	.323
129 5	375	85.0	.337	.339	.324

Table 8.5. Pork loin roasts' analysis of variance for dependent variables found to be significant for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Heating rate (°C/min)					
Regression	5	0.23606	0.04721	2.7956[a]	$F_{5,8(0.095)}=2.80$
Residual	8	0.13511	0.01689	S.	
Lack of fit	4	0.07757	0.01939	1.3482	$F_{4,4(0.20)}=2.48$[d]
Pure error	4	0.05754	0.01438	N.S.	
Total	13	0.37117	0.02855		
Cooking loss (total cooking loss, %)					
Regression	5	140.18	28.04	2.6272[a]	$F_{5,8(0.108)}=2.63$
Residual	8	85.37	10.67	S.	
Lack of fit	4	33.56	8.39	0.6479	$F_{4,4(0.20)}=2.48$
Pure error	4	51.81	12.95	N.S.	
Total	13	225.55	17.35		
Cooking loss (evaporation loss, %)					
Regression	5	122.15	24.43	3.0627[a]	$F_{5,8(0.078)}=3.06$
Residual	8	63.81	7.98	S.	
Lack of fit	4	11.23	2.81	0.2136	$F_{4,4(0.20)}=2.48$
Pure error	4	52.58	13.14	N.S.	
Total	13	185.96	14.30		
Cooking time (min).					
Regression	5	13556.70	2711.33	4.1500[a]	$F_{5,8(0.037)}=4.15$
Residual	8	5227.11	653.39	S.	
Lack of fit	4	2872.52	718.13	1.2199	$F_{4,4(0.20)}=2.48$
Pure error	4	2354.59	588.65	N.S.	
Total	13	18783.80	1444.91		

Table B.5. Pork loin roasts' analysis of variance for dependent variables found to be significant for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
Percent total moisture (% TM)					
Regression	5	83.29	16.66	3.8015[a]	$F_{5,8(0.046)}=3.80$
Residual	8	35.06	4.38	S.	
Lack of fit	4	18.18	4.54	1.0771	$F_{4,4(0.20)}=2.48$[d]
Pure error	4	16.88	4.22	N.S.	
Total	13	118.35	9.10		
Proteolytic enzyme activity (at 0°C)(absorbance units, 520 nm)					
Regression	5	0.48388×10^{-3}	0.96775×10^{-4}	24.9902[a]	$F_{5,8(0.0001)}$ =24.99
Residual	8	0.30980×10^{-4}	0.38275×10^{-5}	S.	
Lack of fit	4	0.15780×10^{-4}	0.39450×10^{-5}	1.0382	$F_{4,4(0.20)}=2.48$
Pure error	4	0.15200×10^{-4}	0.38000×10^{-5}	N.S.	
Total	13	0.51486×10^{-3}	0.39604×10^{-4}		
Total nitrogen (mg N/mg meat, dry weight basis)					
Regression	5	0.11401×10^{-2}	0.22802×10^{-3}	14.2277[a]	$F_{5,8(0.0008)}=14.23$
Residual	8	0.12821×10^{-3}	0.16027×10^{-4}	S.	
Lack of fit	4	0.66058×10^{-6}	0.16514×10^{-4}	1.0630	$F_{4,4(0.477)}=1.06$
Pure error	4	0.62154×10^{-4}	0.15539×10^{-4}	N.S.	
Total	13	0.12683×10^{-2}	0.97562×10^{-4}		
Total nitrogen (% TN, dry weight basis)					
Regression	5	11.40	2.28	14.2277[a]	$F_{5,8(0.0008)}=14.23$
Residual	8	1.28	0.16	S.	
Lack of fit	4	0.66	0.17	1.0628	$F_{4,4(0.48)}=1.063$
Pure error	4	0.62	0.16	N.S.	
Total	13	12.68	0.98		

Table B.5. Pork loin roasts' analysis of variance for dependent variables found to be significant for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
"Remaining" protein fraction [TN - (LIS + NPN) mg N/mg meat, dry weight basis]					
Regression	5	0.90399×10^{-3}	0.18078×10^{-3}	14.9834[a]	$F_{5,8(0.0007)}=14.98$
Residual	8	0.96532×10^{-4}	0.12066×10^{-4}	S.	
Lack of fit	4	0.35491×10^{-4}	0.08873×10^{-4}	0.5814	$F_{4,4(0.20)}=2.48^{d}$
Pure error	4	0.61041×10^{-4}	0.15260×10^{-4}	N.S.	
Total	13	0.10005×10^{-2}	0.76963×10^{-4}		
Chromaticity coordinate, z					
Regression	5	0.32424×10^{-3}	0.64848×10^{-4}	4.6287[a]	$F_{5,7(0.0348)}=4.63$
Residual	8	0.98069×10^{-4}	0.14010×10^{-4}	S.	
Lack of fit	4	0.59269×10^{-4}	0.19756×10^{-4}	2.0367	$F_{3,4(0.20)}=2.48$
Pure error	4	0.38800×10^{-4}	0.97000×10^{-5}	N.S.	
Total	13	0.42231×10^{-3}	0.35192×10^{-4}		
Juiciness (1 = very dry; 5 = very juicy)					
Regression	5	2.306	0.461	2.8708[a]	$F_{5,7(0.1009)}=2.87$
Residual	8	1.125	0.161	S.	
Lack of fit	3	0.485	0.162	1.0100	$F_{3,4(0.20)}=2.48$
Pure error	4	0.640	0.160	N.S.	
Total	13	3.431	0.286		

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P < 0.10$).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P < 0.20$ was used during exploratory work and then $P < 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

Table B.6. Lamb loin roasts. Heating rates, cooking data, and cooking times, with cooking temperature-endpoint temperatures (CT-ET) for the central composite rotatable design (CCRD).

Code/CCRD Number n = 25	Cooking Temp.	Endpoint Temp.	Heating Rate (°C/g)	(°C/min)	Total %	Cooking Loss Drip %	Evaporation %	Cooking Time (min)
160R	428	85.6	.2010	1.3323	30.618	11.669	18.949	64.25
160X	428*	85.6	.1922	1.1560	32.775	11.059	21.716	70.50
265	375*	60.3	.1261	1.4357	12.027	3.012	9.015	42.00
265R	375	62.0	.1555	1.3549	12.125	3.847	8.278	43.25
555	300*	75.0	.1898	0.9260	15.949	5.299	10.650	80.45
555R	300	74.9	.1933	0.9478	16.166	5.625	10.541	74.70
683	450*	75.0	.1464	1.3496	21.871	8.214	13.657	55.20
683R	450	75.0	.1982	1.5933	24.322	7.297	17.025	44.50
691	322*	64.2	.1435	1.2351	11.643	2.073	9.570	51.01
691R	322	64.8	.1393	1.0867	9.912	2.936	6.986	56.01
739	428*	64.8	.1397	1.5190	20.604	7.160	13.444	42.00
739R	428	65.0	.1112	1.2633	15.754	0.126	15.628	49.00
767	375*	90.3	.2021	1.1667	33.855	12.799	21.056	77.40
767R	375	90.5	.2546	1.4521	27.350	8.753	18.597	59.50
890	322*	85.6	.1806	0.9799	23.465	8.203	15.262	82.25
890R	322	85.6	.2008	0.8932	25.456	7.664	17.792	91.25
154 1	375*	75.0	.1888	1.3112	24.163	7.022	17.141	57.20
154R1	375	75.0	.2054	1.3198	23.465	10.499	12.966	54.25
882 2	375*	75.2	.1546	1.1437	25.272	8.966	16.306	65.75
882R2	375	75.2	.1883	1.1695	26.071	9.848	16.223	61.65
926R3	375	75.5	.1963	1.1610	22.216	5.582	16.634	61.50
157 4	375*	75.0	.1632	1.1870	23.832	11.201	12.631	61.50
157R4	375	78.0	.1634	1.0948	24.469	10.035	14.434	67.50
888 5	375	75.0	.1592	1.1058	24.312	7.801	16.511	63.30
888L5	375*	75.3	.1690	1.0772	27.873	10.411	17.462	66.75

* denotes first replication

Table B.7. Significant values of lamb loin roast for cooking temperatures, and moisture ($P \leq 0.10$).

Code/CCRD Number n = 13	Cooking Temp. (°F)	Endpoint Temp. (°C)	Expressible Moisture Index (EMI)	Percent Total Moisture (% TM)	Total Nitrogen (mg N/mg lamb) wet weight basis
160X	428	85.6	.319	64.561	.044319
265	375	60.3	.185	70.090	.037832
555	300	75.0	.216	68.246	.039869
683	450	75.0	.227	68.190	.040364
691	322	64.2	.198	70.232	.038687
739	428	64.8	.211	70.454	.040562
767	375	90.3	.270	63.763	.057189
890	322	85.6	.223	66.080	.044116
154 1	375	75.0	.244	69.057	.042538
882 2	375	75.2	.260	66.188	.046388
926 3	375	75.0	.255	70.492	.039795
157 4	375	75.0	.220	67.041	.043459
888L5	375	75.3	.287	64.938	.040037

Table B.8. Lamb loin roasts. Mean values of chromaticity coordinates; Hunter a_L value; and saturation index.

Code/CCRD Number n = 13	Cooking Temp. (oF)	Endpoint Temp. (oC)	Chromaticity Coordinate[1]			Saturation[2] Index
			x	y	z	
160X	428	85.6	.344	.349	.307	7.97
265	375	60.3	.373	.341	.286	13.45
555	300	75.0	.359	.348	.293	9.57
683	450	75.0	.350	.344	.305	8.36
691	322	64.2	.388	.335	.277	16.18
739	428	64.8	.372	.340	.288	12.51
767	375	90.3	.351	.334	.314	8.61
890	322	85.6	.344	.350	.306	8.53
154 1	375	75.0	.345	.353	.302	8.75
882 2	375	75.2	.341	.348	.312	8.21
926 3	375	75.0	.356	.343	.301	9.15
157 4	375	75.0	.344	.350	.306	8.31
888L5	375	75.3	.340	.348	.311	8.10

[1] Not significant, but given for discussion.

[2] Formula was $((a_L**2 + b_L**2)**0.5)$

Table B.9. Lamb loin roasts. Mean values of sensory evaluation of quality characteristics.

Code/CCRD Number n = 13	Cooking Temp. (°F)	Endpoint Temp. (°C)	Doneness[1]	Color[2]
160X	428	85.6	3.00	4.20
265	375	60.3	2.00	2.00
555	300	75.0	2.70	2.00
683	450	75.0	3.00	3.00
691	322	64.4	2.30	1.60
739	428	64.8	1.90	1.90
767	375	90.3	3.10	3.00
890	322	85.6	3.00	3.30
154 1	375	75.0	3.10	3.40
882 2	375	75.2	2.90	4.30
926 3	375	75.0	2.70	2.50
157 4	375	75.0	2.70	3.70
888L5	375	75.3	3.00	4.60

[1] Doneness (1 = very undercooked, 5 = very overcooked)
[2] Color (1 = rosy red, 5 = brownish grey)

Table B.10. Lamb loin roasts' analysis of variance for dependent variables found to be significant for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Heating rate (°C/g)					
Run	1	0.00015×10^{-2}	0.00150×10^{-3}	0.0021^{b} N.S.	$F_{1,6(0.20)}=2.07$
Regression (CT*ET)	5	0.01300	0.26000×10^{-2}	3.5724^{b} S.	$F_{5,6(0.0764)}=3.57$
Run*Regression	5	0.05652×10^{-2}	0.11304×10^{-3}	0.1553^{b} N.S.	$F_{5,6(0.20)}=2.08$
Residual	13	0.63458×10^{-2}	0.48814×10^{-3}	——	———
Lack of fit	6	0.43668×10^{-2}	0.72780×10^{-3}	2.5744	$F_{6,7(0.1209)}=2.57^{d}$
Pure error	7	0.19790×10^{-2}	0.28272×10^{-3}	S.	———
Total	24	0.02372	0.98828×10^{-3}	——	———
Heating rate (°C/min)					
Run	1	0.00003	0.00003	0.0011^{b} N.S.	$F_{1,6(0.20)}=2.07$
Regression (CT*ET)	5	0.50548	0.10110	3.6273^{b} S.	$F_{5,6(0.0741)}$ $=3.6273$
Run*Regression	5	0.02055	0.00411	0.1475^{b} N.S.	$F_{5,6(0.20)}=2.08$
Residual	13	0.22780	0.01752	——	———
Lack of fit	6	0.16727	0.00028	3.2232 S.	$F_{6,7(0.0756)}=3.22$
Pure error	7	0.06053	0.00865	——	———
Total	24	0.80660	0.33608	——	———

Table B.10. Lamb loin roasts' analysis of variance for dependent variables found to be significant for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
<u>Cooking loss (total cooking loss, %)</u>					
Run	1	0.23	0.23	0.0545^{a} N.S.	$F_{1,13(0.20)}=1.82$
Regression (CT*ET)	5	857.78	171.56	40.6218^{a} S.	$F_{5,13(0.0001)}=40.62$
Run*Regression	5	20.24	4.05	0.9587^{a} N.S.	$F_{5,13(0.20)}=1.72$
Residual	13	54.90	4.22	——	——
Lack of fit	6	34.13	5.69	1.9168	$F_{6,7(0.20)}=1.96$
Pure error	7	20.77	2.97	N.S.	——
Total	24	1023.21	42.63	——	——
<u>Cooking loss (drip loss, %)</u>					
Run	1	0.06	0.06	0.0193^{a} N.S.	$F_{1,13(0.20)}=1.82$
Regression (CT*ET)	5	179.14	35.83	11.9112^{a} S.	$F_{5,13(0.0002)}$ $=11.91$
Run*Regression	5	20.97	4.19	1.3943^{a} N.S.	$F_{5,13(0.2894)}=1.39$
Residual	13	39.10	3.01	——	——
Lack of fit	6	11.83	1.97	0.5060	$F_{6,7(0.20)}=1.96$
Pure error	7	27.27	3.90	N.S.	——
Total	24	256.72	10.70	——	——

Table B.10. Lamb loin roasts' analysis of variance for dependent variables found to be significant for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
Cooking loss (evaporation loss, %)					
Run	1	0.52	0.52	0.1481[a] N.S.	$F_{1,13(0.20)}=1.82$
Regression (CT*ET)	5	273.04	54.61	15.5574[a] S.	$F_{5,13(0.0001)}=15.56$
Run*Regression	5	17.42	3.48	0.9925[a] N.S.	$F_{5,13(0.20)}=1.72$
Residual	13	45.63	3.51	——	——
Lack of fit	6	19.92	3.32	0.9036	$F_{6,7(0.20)}=1.96$
Pure error	7	25.72	3.67	N.S.	——
Total	24	367.58	15.32	——	——
Cooking time (min).					
Run	1	1.12	1.12	0.0152[b] N.S.	$F_{1,6(0.20)}=2.07$
Regression (CT*ET)	5	3430.96	686.19	9.2813[b] S.	$F_{5,6(0.0086)}=9.28$[d]
Run*Regression	5	18.70	3.74	0.0506[b] N.S.	$F_{5,6(0.20)}=2.08$
Residual	13	595.32	45.79	——	——
Lack of fit	6	443.59	73.93	3.4108 S.	$F_{6,7(0.0667)}=3.41$
Pure error	7	151.73	21.68	——	——
Total	24	4062.54	169.27	——	——

Table B.10. Lamb loin roasts' analysis of variance for dependent variables found to be significant for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Expressible moisture index (EMI)					
Regression	5	0.01363	0.00267	5.0692[a]	$F_{5,7(0.0278)}=5.07$
Residual	7	0.00369	0.00053	S.	
Lack of fit	3	0.00131	0.00044	0.7349	$F_{3,4(0.20)}=2.48$[d]
Pure error	4	0.00238	0.00059	N.S.	
Total	12	0.01705	0.00142		
Percent total moisture (% TM)					
Regression	5	48.32	9.66	3.4086[a]	$F_{5,7(0.0704)}=3.41$
Residual	7	19.84	2.84	S.	
Total	12	68.16	5.68		
Total nitrogen (TN/mg meat, wet weight basis)					
Regression	5	0.21443×10^{-3}	0.42887×10^{-4}	4.1513[a]	$F_{5,6(0.0562)}=4.15$
Residual	6	0.61985×10^{-4}	0.10331×10^{-4}	S.	
Lack of fit	2	0.32580×10^{-4}	0.16290×10^{-4}	2.2160	$F_{2,4(0.20)}=2.47$[d]
Pure error	4	0.29405×10^{-4}	0.73513×10^{-5}	N.S.	
Total	11	0.27642×10^{-3}	0.25129×10^{-4}		
Total nitrogen (% TN, wet weight basis)					
Regression	5	2.14433	0.42887	4.1513[a]	$F_{5,6(0.0562)}=4.15$
Residual	6	0.61985	0.10331	S.	
Lack of fit	2	0.32580	0.16290	2.2160	$F_{2,4(0.20)}=2.47$
Pure error	4	0.29405	0.07351	N.S.	
Total	11	2.76419	0.25129		

Table B.10. Lamb loin roasts' analysis of variance for dependent variables found to be significant for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	$F_{table}{}^{c}$
Chromaticity coordinate, x					
Regression	5	0.22630×10^{-2}	0.45260×10^{-3}	8.4237[a]	$F_{5,7(0.0071)}=8.42$
Residual	7	0.37610×10^{-3}	0.53729×10^{-4}	S.	
Lack of fit	3	0.21330×10^{-3}	0.71100×10^{-4}	1.7469	$F_{3,4(0.20)}=2.48$
Pure error	4	0.16280×10^{-3}	0.40700×10^{-4}	N.S.	
Total	12	0.26391×10^{-2}	0.21992×10^{-3}		
Chromaticity coordinate, z					
Regression	5	0.13687×10^{-2}	0.27374×10^{-3}	12.2555[a]	$F_{5,7(0.0024)}=12.26$
Residual	7	0.15635×10^{-3}	0.22336×10^{-4}	S.	
Lack of fit	3	0.55153×10^{-4}	0.18384×10^{-4}	0.7266	$F_{3,4(0.20)}=2.48$
Pure error	4	0.10120×10^{-3}	0.25300×10^{-4}	N.S.	
Total	12	0.15251×10^{-2}	0.12709×10^{-3}		
Saturation index ((aL**2 + bL**2)**0.5)					
Regression	5	71.2417	14.2483	6.0848[b]	$F_{5,3(0.0840)}=6.09$
Residual	7	7.7900	1.1129	S.	
Lack of fit	3	7.0249	2.3416	12.2418	$F_{3,4(0.0175)}=12.24$
Pure error	4	0.7651	0.1913	S.	
Total	12	79.0317	6.5860		
Doneness (1 = very undercooked; 5 = very overcooked)					
Regression	5	1.732	0.346	8.9426[a]	$F_{5,7(0.006)}=8.94$
Residual	7	0.271	0.039	S.	
Lack of fit	3	0.143	0.048	1.490	$F_{3,4(0.20)}=2.48$
Pure error	4	0.128	0.032	N.S.	
Total	12	2.003	0.167		

Table B.10. Lamb loin roasts' analysis of variance for dependent variables found to be significant for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
Color (1 = rosy red; 5 = grey brown)					
Regression	5	8.251	1.650	3.2275[a] S.	$F_{5,7(0.0792)}=3.22$
Residual	7	3.579	0.511		
Lack of fit	3	0.879	0.293	0.4342 N.S.	$F_{3,4(0.20)}=2.48$
Pure error	4	2.70	0.675		
Total	12	11.831	0.986		

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P < 0.10$).

b = Lack of Fit Mean Square is the error term (F_{calc} = Regression Mean/Lack of Fit Mean Square) ($P < 0.10$)

c = Number in parentheses = alpha-value denoting level of significance.

d = $P < 0.20$ was used during exploratory work and then $P < 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

f = Due to large variability found between the center point observations' cooking time, the MSLF numbers appeared to be negative and so could not be used. Regression Mean Square/Residual Mean Square, therefore, had to be used for F_{calc}.

Table B.11. Turkey breast roasts. Initial weights, cooking data, heating rates and cooking times, with cooking temperature-endpoint temperatures (CT-ET) for the central composite rotatable design (CCRD).

Code/CCRD Number n=26	Cooking Temp.	Endpoint Temp.		Heating Rate		Cooking Loss		Cooking Time (min)
			(°C/g)	(°C/min)	(°C/g/min)	Total %	Evaporation,%	
248	375*	94.9	.0205	.4603	.000104	37.739	32.309	197.25
248R	375	95.0	.0187	.4526	.000110	36.046	29.032	169.25
327	322*	78.0	.0203	.4105	.000113	27.062	25.611	180.25
327R	322	78.0	.0200	.5769	.000154	15.853	13.694	130.00
538	428*	77.9	.0186	.8076	.000202	27.944	19.903	92.50
538R	428	78.0	.0185	.8739	.000207	25.939	20.697	89.25
605	322	92.0	.0214	.4667	.000113	26.245	20.068	189.00
605R	322*	92.0	.0208	.4103	.000097	29.369	24.022	214.50
715	300	85.0	.0204	.4015	.000103	27.422	17.975	199.25
715R	300*	84.9	.0213	.3616	.000094	28.851	20.698	226.50
808	428*	92.0	.0228	.5597	.000147	36.121	31.031	155.25
808R	428	92.0	.0246	.6447	.000180	36.000	31.354	136.50
841	375*	75.0	.0183	.6494	.000158	20.195	15.368	115.50
841R	375	75.1	.0182	.6051	.000154	25.163	19.495	118.50
997	450*	85.0	.0198	.9357	.000231	23.993	18.409	85.50
997R	450	85.0	.0205	.6585	.000167	29.707	25.107	123.00
881 1	375*	85.1	.0183	.5103	.000114	30.774	18.495	160.50
881R1	375	85.0	.0194	.6641	.000151	27.117	18.668	128.00
761 2	375*	84.5	.0208	.5552	.000143	33.088	26.116	145.00
761R2	375	85.0	.0214	.6093	.000154	31.177	24.563	139.50
056 3	375*	85.0	.0192	.4897	.000113	33.561	33.988	169.50
056R3	375	85.0	.0185	.5325	.000120	31.085	23.593	154.00
733 4	375*	85.3	.0228	.5508	.000154	31.724	26.546	148.50
733R4	375	85.1	.0206	.6620	.000168	26.998	21.803	122.50
697 5	375*	85.0	.0193	.5889	.000142	26.552	18.319	135.50
697R5	375	85.0	.0204	.6091	.000162	25.935	21.821	125.75

Table B.12. Turkey breast roasts. Mean values for cooking temperature, non-protein nitrogen (NPN) extract for wet and dry weight basis,, total nitrogen (TN), low ionic strength (LIS) soluble protein fraction, and "remaining" protein fraction.

Code/CCRD Number	Cooking Temp. (^{o}F)	Endpoint Temp. (^{o}C)	Non-protein[1] Nitrogen wet	Total Nitrogen mg N/mg meat, dry	Low Ionic Strength	"Remaining" Protein Fraction
248	375	95.0	.003649	.152184	.013036	.127921
327	322	78.0	.004585	.156837	.015436	.126233
538	428	77.9	.005017	.140472	.015843	.111327
605R	322	92.0	.004308	.154638	.013989	.127312
715R	300	85.0	.004421	.151968	.018338	.119973
808	428	92.0	.004851	.160576	.014951	.130879
841	375	75.1	.004149	.130096	.012378	.103969
997	450	85.0	.005304	.149199	.017245	.115288
881 1	375	85.1	.004287	.146427	.013980	.119768
761 2	375	84.5	.004351	.158280	.013210	.132108
056 3	375	85.0	.004208	.159336	.013055	.133652
733 4	375	85.1	.004662	.157906	.014667	.128801
697 5	375	85.0	.004578	.160286	.015701	.130071

Table B.13. Turkey thigh roasts. Mean values for inital cooking temperature data and the sensory evaluation of the quality characteristic juiciness.

Code/CCRD Number n=13	Cooking Temp. (°F)	Cookingt Time min.[1]	Juiciness[1]
248	375	197.25	2.10
327R	322	130.00	3.20
538	428	92.50	2.70
605R	322	214.50	2.90
715R	300	226.50	3.00
808	428	155.25	2.00
841	375	115.50	2.70
997	450	85.50	2.40
881 1	375	160.50	2.50
761 2	375	145.00	2.30
056 3	375	169.50	2.60
733 4	375	148.50	2.40
697 5	375	135.50	2.80

[1] Cooking time was used instead of ET (°C as the second independent variable for turkey breast, as ET did not reflect the thigh ETs at al.

[2] Juiciness (1 = very dry, 5 = very juicy).

Table B.14. Data, means and standard deviations for cooking data for control, "checking" (CKPM) turkey halves.

Code/CCRD Number n =	Cooking Temp.	Endpoint Temp.	Total Cooking Loss, % 6	Evaporation Loss, % 6	Cooking Time 6	Heating Rates			Sensory Juiciness 5	TN (mg) dry weight 4	NPN wet weight 4	LIS dry weight 4	REM dry weight 4
						°C/g 6	°C/min 6	°C/g/min 6					
234/C1	350	80.0	21.10	15.67	121.0	0.0181	0.6364	0.000150	3.40				
343/C2	350	79.5	26.48	20.09	156.5	0.0172	0.4824	0.000110	2.00	0.146437	0.007081	−0.000640	0.102645
649/C3	350	80.0	25.76	17.82	139.0	0.0188	0.5489	0.000135	2.40	0.156131	0.004751	−0.003131	0.128990
408/C4	350	80.0	27.00	17.90	150.0	0.0158	0.5087	0.000106	2.20	0.141467	0.004809	−0.001247	0.113308
924/C5	350	80.0	26.45	20.10	162.0	0.0163	0.4722	0.000100	2.60	0.159238	0.004825	0.001120	0.127625
999/C6	350	80.0	27.82	18.58	159.0	0.0189	0.4906	0.000119					
Mean + SD			25.77 + 2.18	18.36 + 1.52	147.92 +14.16	0.0175167 +0.0011852	0.5232 +0.0563	0.000120 +0.174260 x 10^{-4}	2.52 +0.48	0.15081825 +0.71721460 x 10^{-2}	0.0053665 +0.9902490 x 10^{-3}	−0.0009745 +0.1518516 x 10^{-2}	0.11814200 +0.01085273

Table B.15. Turkey breast roasts' and turkey thigh roasts' analysis of variance table for dependent variables found to be significant for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
<u>TURKEY BREAST ROAST</u>					
<u>Heating rate (°C/g)</u>					
Run	1	0.10300×10^{-7}	0.10300×10^{-7}	0.0048^{a} N.S.	$F_{1,14(0.20)}=1.81$
Regression (CT*ET)	5	0.30241×10^{-4}	0.06048×10^{-4}	2.8371^{a} S.	$F_{5,14(0.0567)}=2.84$
Run*Regression	5	0.02586×10^{-4}	0.51728×10^{-6}	0.2427^{a} N.S.	$F_{5,14(0.20)}=1.70$
Residual	14	0.29835×10^{-4}	0.21311×10^{-5}	——	———
Lack of fit	6	0.13295×10^{-4}	0.20492×10^{-4}	——	———
Pure error	8	0.17540×10^{-4}	0.21925×10^{-5}	0.9346 N.S.	$F_{6,8(0.20)}=1.88^{d}$
Total	25	0.62578×10^{-4}	———	——	———
<u>Heating rate (°C/min)</u>					
Run	1	0.0	0.0	0.0000^{b} N.S.	$F_{1,6(0.20)}=2.07$
Regression (CT*ET)	5	0.39448	0.07890	10.9381^{b} S.	$F_{5,6(0.0056)}=10.94$
Run*Regression	5	0.03529	0.00706	0.9784^{b} N.S.	$F_{5,6(0.20)}=2.08$
Residual	14	0.06092	0.00435	——	———
Lack of fit	6	0.04328	0.00721	——	———
Pure error	8	0.01764	0.00220	3.2715 S.	$F_{6,8(0.0625)}=2.67^{d}$
Total	25	0.49368	——	——	———

Table B.15. Turkey breast roasts' and turkey thigh roasts' analysis of variance table for dependent variables found to be significant for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
Cooking loss (total cooking loss, %)					
Run	1	0.41	0.41	0.0180[b] N.S.	$F_{1,6(0.20)}=2.07$
Regression (CT*ET)	5	376.01	75.20	3.2860[b] S.	$F_{5,6(0.0899)}=3.29$
Run*Regression	5	43.86	8.77	6.3833[b] N.S.	$F_{5,6(0.20)}=2.08$
Residual	14	193.08	13.79	——	——
Lack of fit	6	137.31	22.88	——	——
Pure error	8	55.77	B.157	3.2827 S.	$F_{6,8(0.0620)}=2.67$[d]
Total	25	620.77	——	——	——
Cooking loss (evaporation loss, %)					
Run	1	2.80	2.80	0.1421[a] N.S.	$F_{1,14(0.20)}=1.81$
Regression (CT*ET)	5	360.23	72.04	3.6626[a] S.	$F_{5,14(0.025)}=3.66$
Run*Regression	5	71.23	14.25	0.7242[a] N.S.	$F_{5,14(0.20)}=1.70$
Residual	14	275.38	19.67	——	——
Lack of fit	6	84.25	14.04	——	——
Pure error	8	191.14	23.89	0.5877 N.S.	$F_{6,8(0.20)}=1.88$
Total	25	711.48	——	——	——

Table B.15. Turkey breast roasts' and turkey thigh roasts' analysis of variance table for dependent variables found to be significant for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
Cooking time (min).					
Run	1	181.40	181.40	0.8522[a] N.S.	$F_{1,14(0.20)}=1.81$
Regression (CT*ET)	5	28914.01	5782.80	27.1659[a] S.	$F_{5,14(0.0001)}=27.17$
Run*Regression	5	2532.30	506.46	2.3792[a] N.S.	$F_{5,14(0.10)}=2.31$
Residual	14	2980.21	213.87	----	------
Lack of fit	6	1601.86	268.158	----	------
Pure error	8	1378.35	172.29	1.5495 N.S.	$F_{6,8(0.20)}=1.88$[d]
Total	25	34744.90	----	----	------
Heating rate (°C/g/min).					
Run	1	0.00831×10^{-8}	0.00083×10^{-7}	0.2282[a] N.S.	$F_{5,14(0.20)}=1.70$
Regression (CT*ET)	5	0.24015×10^{-7}	0.48030×10^{-8}	13.1872[a] S.	$F_{5,14(0.0001)}=13.19$
Run*Regression	5	0.24260×10^{-8}	0.00485×10^{-7}	1.3322[a] N.S.	$F_{5,14(0.20)}=1.70$
Residual	14	0.50990×10^{-8}	0.03642×10^{-8}	----	------
Lack of fit	6	0.23362×10^{-8}	0.03894×10^{-8}	----	------
Pure error	8	0.27628×10^{-8}	0.34535×10^{-9}	1.1375 N.S.	$F_{6,8(0.20)}=1.88$
Total	25	0.31786×10^{-7}	----	----	------

Table B.15. Turkey breast roasts' and turkey thigh roasts' analysis of variance table for dependent variables found to be significant for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Non-protein nitrogen (NPN) extract (mg N/mg meat, wet weight basis)					
Regression	5	0.17589×10^{-5}	0.35178×10^{-6}	6.847^{a}	$F_{5,7(0.013)}=6.85$
Residual	7	0.35963×10^{-6}	0.51375×10^{-7}	S.	
Lack of fit	3	0.20870×10^{-7}	0.69580×10^{-8}	1.844	$F_{3,4(0.20)}=2.48^{d}$
Pure error	4	0.15088×10^{-6}	0.37721×10^{-7}	N.S.	
Total	13	0.21185×10^{-5}	0.17654×10^{-6}		
Total nitrogen (TN/mg meat, dry weight basis)					
Regression	5	0.68378×10^{-3}	0.13676×10^{-3}	3.569^{a}	$F_{5,7(0.064)}=3.57$
Residual	7	0.26817×10^{-3}	0.38310×10^{-4}	S.	
Lack of fit	3	0.13919×10^{-4}	0.46398×10^{-5}	1.439	$F_{3,4(0.20)}=2.48$
Pure error	4	0.13897×10^{-3}	0.32243×10^{-4}	N.S.	
Total	13	0.95194×10^{-3}	0.79329×10^{-4}		
Total nitrogen (% TN, dry weight basis)					
Regression	5	6.83776	1.36755	3.569^{a}	$F_{5,7(0.064)}=3.57$
Residual	7	2.68167	0.38310	S.	
Lack of fit	3	1.39100	0.46398	1.4389	$F_{3,4(0.20)}=2.48$
Error	4	1.28973	0.32243	N.S.	
Total	13	9.51942	0.79329		
Low ionic strength (LIS) soluble protein fraction (mg N/mg meat, dry weight basis)					
Regression	5	0.29353×10^{-4}	0.58706×10^{-5}	5.5964^{a}	$F_{5,7(0.022)}=5.60$
Residual	7	0.73430×10^{-5}	0.10490×10^{-5}	S.	
Lack of fit	3	0.25624×10^{-5}	0.08510×10^{-5}	0.7146	$F_{3,4(0.20)}=2.48$
Pure error	4	0.47807×10^{-5}	0.11952×10^{-5}	N.S.	
Total	13	0.36696×10^{-4}	0.30580×10^{-5}		

Table B.15. Turkey breast roasts' and turkey thigh roasts' analysis of variance table for dependent variables found to be significant for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
"Remaining" protein fraction [TN - (LIS + NPN) mg N/mg meat, dry weight basis]					
Regression	5	0.71536×10^{-3}	0.14307×10^{-3}	3.970^{a}	$F_{5,7(0.05)}=3.97$
Residual	7	0.25228×10^{-3}	0.36040×10^{-4}	S.	
Lack of fit	3	0.01346×10^{-3}	0.44877×10^{-5}	1.525	$F_{3,4(0.20)}=2.48^{d}$
Pure error	4	0.11764×10^{-3}	0.29413×10^{-4}	N.S.	
Total	13	0.96763×10^{-3}	0.80636×10^{-4}		
TURKEY THIGH					
Juiciness (1 = very dry; 5 = very juicy)					
Regression	5	1.235	0.247	7.7815^{a}	$F_{5,7(0.009)}=7.78$
Residual	7	0.222	0.032	S.	
Lack of fit	3	0.074	0.025	0.6680	$F_{3,4(0.20)}=2.48$
Pure error	4	0.148	0.037	N.S.	
Total	13	1.457	0.131		

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P < 0.10$).

b = Lack of Fit Mean Square used as the error term (F_{calc} = Regression Mean Square/Lack of Fit Mean Square) ($P < 0.10$).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P < 0.20$ was used during exploratory work and then $P < 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

APPENDIX C

ANOVA Tables

Table C.1. - C.23. Analysis of Variance Tables

Table C.1. Pork loin roasts' analysis of variance of initial weights, cooking loss data, heating rates, and cooking times for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	$F_{table}{}^{c}$
Initial weight (g). (Used as a "dummy variable" to check on regression and analysis of variance results.)					
Regression	5	45678.2	9135.6	0.7753^{a}	$F_{5,8(0.20)}=1.90$
Residual	8	94268.5	11783.6	N.S.	
Lack of fit	4	24788.8	6197.2	0.3568	$F_{4,4(0.20)}=2.48^{d}$
Pure error	4	69479.7	17369.9	N.S.	
Total	13	139947.0	10765.1		
Heating rate (°C/g)					
Regression	5	0.56804×10^{-2}	0.11361×10^{-3}	1.9889^{a}	$F_{5,8(0.20)}=1.90$
Residual	8	0.45697×10^{-3}	0.57122×10^{-4}	N.S.	
Lack of fit	4	0.14546×10^{-3}	0.36366×10^{-4}	0.4670	$F_{4,4(0.20)}=2.48$
Pure error	4	0.31151×10^{-3}	0.77877×10^{-4}	N.S.	
Total	13	0.10250×10^{-2}	0.78847×10^{-4}		
Heating rate (°C/min)					
Regression	5	0.23606	0.04721	2.7956^{a}	$F_{5,8(0.095)}=2.80$
Residual	8	0.13511	0.01689	S.	
Lack of fit	4	0.07757	0.01939	1.3482	$F_{4,4(0.20)}=2.48$
Pure error	4	0.05754	0.01438	N.S.	
Total	13	0.37117	0.02855		
Cooking loss (total cooking loss, %)					
Regression	5	140.18	28.04	2.6272^{a}	$F_{5,8(0.108)}=2.63$
Residual	8	85.37	10.67	S.	
Lack of fit	4	33.56	8.39	0.6479	$F_{4,4(0.20)}=2.48$
Pure error	4	51.81	12.95	N.S.	
Total	13	225.55	17.35		
Cooking loss (drip loss, %)					
Regression	5	30.32	6.06	1.4238^{a}	$F_{5,8(0.20)}=1.90$
Residual	8	34.07	4.26	N.S.	
Lack of fit	4	17.56	4.39	1.0637	$F_{4,4(0.20)}=2.48$
Pure error	4	16.51	4.13	N.S.	
Total	13	64.39	4.95		

Table C.1. Pork loin roasts' analysis of variance of initial weights, cooking loss data, heating rates, and cooking times for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Cooking loss (evaporation loss, %)					
Regression	5	122.15	24.43	3.0627^{a}	$F_{5,8(0.078)}=3.06$
Residual	8	63.81	7.98	S.	
Lack of fit	4	11.23	2.81	0.2136	$F_{4,4(0.20)}=2.48^{d}$
Pure error	4	52.58	13.14	N.S.	
Total	13	185.96	14.30		
Cooking time (min).					
Regression	5	13556.70	2711.33	4.1500^{a}	$F_{5,8(0.037)}=4.15$
Residual	8	5227.11	653.39	S.	
Lack of fit	4	2872.52	718.13	1.2199	$F_{4,4(0.20)}=2.48$
Pure error	4	2354.59	588.65	N.S.	
Total	13	18783.80	1444.91		
Heating rate (°C/g/min).					
Regression	5	0.31708×10^{-6}	0.63416×10^{-7}	2.3146^{a}	$F_{5,8(0.139)}=2.32$
Residual	8	0.21918×10^{-6}	0.27398×10^{-7}	N.S.	
Lack of fit	4	0.10327×10^{-6}	0.25800×10^{-7}	0.8909	$F_{4,4(0.20)}=2.48$
Pure error	4	0.11592×10^{-6}	0.28979×10^{-7}	N.S.	
Total	13	0.53626×10^{-6}	0.41251×10^{-7}		

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leq 0.10$).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P \leq 0.20$ was used during exploratory work and then $P \leq 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

Table C.2. Pork loin roasts' analysis of variance of expressible moisture index (EMI), percent total moisture, proteolytic enzyme values, cooking data, heating rates, cooking times, and enzyme weight for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Expressible moisture index (EMI)					
Regression	5	0.01022	0.00204	0.8994^{b}	$F_{5,4(0.20)}=2.48$
Residual	8	0.01237	0.00155	N.S.	
Lack of fit	4	0.00909	0.00227	2.7684	$F_{4,4(0.17)}=2.77^{d}$
Pure error	4	0.00328	0.00082	S.	
Total	13	0.02259	0.00174		
Percent total moisture (% TM)					
Regression	5	83.29	16.66	3.8015^{a}	$F_{5,8(0.046)}=3.80$
Residual	8	35.06	4.38	S.	
Lack of fit	4	18.18	4.54	1.0771	$F_{4,4(0.20)}=2.48$
Pure error	4	16.88	4.22	N.S.	
Total	13	118.35	9.10		
Proteolytic enzyme activity (at 0°C)(absorbance units, 520 nm)					
Regression	5	0.48388×10^{-3}	0.96775×10^{-4}	24.9902^{a}	$F_{5,8(0.0001)}$ $=24.99$
Residual	8	0.30980×10^{-4}	0.38275×10^{-5}	S.	
Lack of fit	4	0.15780×10^{-4}	0.39450×10^{-5}	1.0382	$F_{4,4(0.20)}=2.48$
Pure error	4	0.15200×10^{-4}	0.38000×10^{-5}	N.S.	
Total	13	0.51486×10^{-3}	0.39604×10^{-4}		
Proteolytic enzyme activity (at 37°C)(absorbance units, 520 nm)					
Regression	5	0.03185×10^{-4}	0.63695×10^{-4}	2.3387^{a}	$F_{5,8(0.14)}=2.34$
Residual	8	0.02179×10^{-4}	0.27235×10^{-4}	N.S.	
Lack of fit	4	0.10908×10^{-5}	0.27270×10^{-4}	1.0026	$F_{4,4(0.20)}=2.48$
Pure error	4	0.01088×10^{-4}	0.27200×10^{-4}	N.S.	
Total	13	0.05364×10^{-4}	0.41258×10^{-4}		
Proteolytic enzyme activity difference [(37 - 0)°C](absorbance units, 520 nm)					
Regression	5	0.88878×10^{-4}	0.17776×10^{-4}	0.4232^{a}	$F_{5,8(0.20)}=1.90$
Residual	8	0.03360×10^{-4}	0.42006×10^{-4}	N.S.	
Lack of fit	4	0.15285×10^{-5}	0.38210×10^{-4}	0.8343	$F_{4,4(0.20)}=2.48$
Pure error	4	0.01832×10^{-4}	0.45800×10^{-4}	N.S.	
Total	13	0.04249×10^{-4}	0.32687×10^{-4}		

Table C.2. Pork loin roasts' analysis of variance of expressible moisture index (EMI), percent total moisture, proteolytic enzyme values, cooking data, heating rates, cooking times, and enzyme weight for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
pH of meat and redistilled water slurry					
Regression	5	0.3989	0.0798	0.8722[b]	$F_{5,4(0.20)}=2.48$
Residual	8	0.3954	0.0494	N.S.	
Lack of fit	4	0.3659	0.0915	12.3950	$F_{4,4(0.02)}=12.40$[d]
Pure error	4	0.0295	0.0074	S.	
Total	13	0.7943	0.0611		
pH of extract, after enzyme removal					
Regression	5	0.4080	0.0816	1.3912[b]	$F_{5,4(0.20)}=2.48$
Residual	8	0.2506	0.0313	N.S.	
Lack of fit	4	0.2346	0.0586	14.6622	$F_{4,4(0.01)}=14.66$
Pure error	4	0.0160	0.0040	S.	
Total	13	0.6586	0.0507		
Warner-Bratzler shear values (kg/1.27 cm core)					
Regression	5	17.5772	3.5154	0.9933[b]	$F_{5,4(0.20)}=2.48$
Residual	8	15.8921	1.9865	N.S.	
Lack of fit	4	14.1558	3.5390	8.1531	$F_{4,4(0.03)}=8.15$
Pure error	4	1.7362	0.4341	S.	
Total	13	33.4693	2.5746		
Enzyme weight (g). (Used as a "dummy" variable to check on regression and analysis of variance results.)					
Regression	5	0.18532	0.03706	1.0169[b]	$F_{5,4(0.20)}=2.48$
Residual	8	0.15158	0.01895	N.S.	
Lack of fit	4	0.14579	0.03645	25.1975	$F_{4,4(0.004)}=25.20$
Pure error	4	0.00579	0.00145	S.	
Total	13	0.33690	0.02592		

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leqslant 0.10$).

b = Lack of Fit Mean Square is the error term (F_{calc} = Regression Mean Square/Lack of Fit Mean Square) ($P \leqslant 0.10$).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P \leqslant 0.20$ were used during exploratory work and then $P \leqslant 0.20$ were used for evaluating significance of the MSLF/MSPE's F_{calc} value.

Table C.3. Pork loin roasts' analysis of variance of total nitrogen, low ionic strength (LIS) protein solubility extract, non-protein nitrogen (NPN) extract, "sarcoplasmic" protein fraction, and "remaining" protein fraction for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
Total nitrogen (TN/mg meat, wet weight basis)					
Regression	5	0.17307×10^{-4}	0.34614×10^{-5}	0.3386[a]	$F_{5,8(0.20)}=1.90$
Residual	8	0.81772×10^{-4}	0.10222×10^{-4}	N.S.	
Lack of fit	4	0.40526×10^{-4}	0.10131×10^{-4}	0.9825	$F_{4,4(0.20)}=2.48$[d]
Pure error	4	0.41246×10^{-4}	0.10312×10^{-4}	N.S.	
Total	13	0.99079×10^{-4}	0.76214×10^{-5}		
Total nitrogen (% TN, wet weight basis)					
Regression	5	0.17307	0.03461	0.3386[a]	$F_{5,8(0.20)}=1.90$
Residual	8	0.81772	0.10222	N.S.	
Lack of fit	4	0.40526	0.10131	0.9825	$F_{4,4(0.20)}=2.48$
Pure error	4	0.41246	0.10312	N.S.	
Total	13	0.99079	0.07622		
Low ionic strength (LIS) soluble protein fraction (mg N/mg meat, wet weight basis)					
Regression	5	0.41222×10^{-5}	0.82443×10^{-6}	1.1603[a]	$F_{5,8(0.20)}=1.90$
Residual	8	0.56844×10^{-5}	0.71056×10^{-6}	N.S.	
Lack of fit	4	0.27514×10^{-5}	0.68785×10^{-6}	0.9381	$F_{4,4(0.20)}=2.48$
Pure error	4	0.29331×10^{-5}	0.73327×10^{-6}	N.S.	
Total	13	0.98066×10^{-5}	0.75436×10^{-6}		
Non-protein nitrogen (NPN) extract (mg N/mg meat, wet weight basis)					
Regression	5	0.12360×10^{-5}	0.24720×10^{-6}	0.8971[a]	$F_{5,8(0.20)}=1.90$
Residual	8	0.22046×10^{-5}	0.27557×10^{-6}	N.S.	
Lack of fit	4	0.20466×10^{-6}	0.51165×10^{-7}	0.1023	$F_{4,4(0.20)}=2.48$
Pure error	4	0.19999×10^{-5}	0.49997×10^{-6}	N.S.	
Total	13	0.34406×10^{-5}	0.26466×10^{-6}		
"Sarcoplasmic" protein fraction nitrogen [(LIS - NPN) mg N/mg meat, wet weight basis]					
Regression	5	0.60772×10^{-5}	0.12154×10^{-5}	0.8784[a]	$F_{5,8(0.20)}=1.90$
Residual	8	0.11069×10^{-4}	0.13836×10^{-5}	N.S.	
Lack of fit	4	0.32110×10^{-5}	0.80277×10^{-6}	0.4086	$F_{4,4(0.20)}=2.48$
Pure error	4	0.78578×10^{-5}	0.19645×10^{-5}	N.S.	
Total	13	0.17146×10^{-4}	0.13190×10^{-5}		

Table C.3. Pork loin roasts' analysis of variance of total nitrogen, low ionic strength (LIS) protein solubility extract, non-protein nitrogen (NPN) extract, "sarcoplasmic" protein fraction, and "remaining" protein fraction for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
"Remaining protein" fraction [TN - (LIS + NPN) mg N/mg meat, wet weight basis					
Regression	5	0.27277×10^{-4}	0.54553×10^{-5}	0.6303[a]	$F_{5,8(0.20)}=1.90$
Residual	8	0.69236×10^{-4}	0.86544×10^{-5}	N.S.	
Lack of fit	4	0.24758×10^{-4}	0.06190×10^{-4}	0.5566	$F_{4,4(0.20)}=2.48$
Pure error	4	0.44478×10^{-4}	0.11120×10^{-4}	N.S.	
Total	13	0.96512×10^{-4}	0.07424		
Total nitrogen (mg N/mg meat, dry weight basis)					
Regression	5	0.11401×10^{-2}	0.22802×10^{-3}	14.2277[a]	$F_{5,8(0.0008)}=14.23$
Residual	8	0.12821×10^{-3}	0.16027×10^{-4}	S.	
Lack of fit	4	0.66058×10^{-6}	0.16514×10^{-4}	1.0630	$F_{4,4(0.477)}=1.06$
Pure error	4	0.62154×10^{-4}	0.15539×10^{-4}	N.S.	
Total	13	0.12683×10^{-2}	0.97562×10^{-4}		
Total nitrogen (% TN, dry weight basis)					
Regression	5	11.40	2.28	14.2277[a]	$F_{5,8(0.0008)}=14.23$
Residual	8	1.28	0.16	S.	
Lack of fit	4	0.66	0.17	1.0628	$F_{4,4(0.48)}=1.063$
Pure error	4	0.62	0.16	N.S.	
Total	13	12.68	0.98		
Low ionic strength (LIS) soluble protein fraction (mg N/mg meat, dry weight basis)					
Regression	5	0.36129×10^{-4}	0.72257×10^{-5}	1.4946[a]	$F_{5,8(0.20)}=1.90$
Residual	8	0.38675×10^{-4}	0.48344×10^{-5}	N.S.	
Lack of fit	4	0.16479×10^{-4}	0.41120×10^{-5}	0.7424	$F_{4,4(0.20)}=2.48$
Pure error	4	0.22196×10^{-4}	0.55491×10^{-5}	N.S.	
Total	13	0.74804×10^{-4}	0.57541×10^{-5}		
Non-protein nitrogen (NPN) extract (mg N/mg meat, dry weight basis)					
Regression	5	0.15140×10^{-4}	0.30279×10^{-5}	1.5651[a]	$F_{5,8(0.20)}=1.90$
Residual	8	0.15477×10^{-4}	0.19346×10^{-5}	N.S.	
Lack of fit	4	0.02761×10^{-4}	0.06903×10^{-5}	0.2171	$F_{4,4(0.20)}=2.48$
Pure error	4	0.12716×10^{-4}	0.31789×10^{-5}	N.S.	
Total	13	0.30617×10^{-4}	0.23551×10^{-5}		

Table C.3. Pork loin roasts' analysis of variance of total nitrogen, low ionic strength (LIS) protein solubility extract, non-protein nitrogen (NPN) extract, "sarcoplasmic" protein fraction, and "remaining" protein fraction for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
"Sarcoplasmic" protein fraction [(LIS - NPN) mg N/mg meat, dry weight basis]					
Regression	5	0.42334×10^{-4}	0.08467×10^{-4}	0.8894^{a}	$F_{5,8(0.20)}=1.90$
Residual	8	0.77057×10^{-4}	0.09632×10^{-4}	N.S.	
Lack of fit	4	0.25056×10^{-4}	0.06264×10^{-4}	0.4818	$F_{4,4(0.20)}=2.48$
Pure error	4	0.52001×10^{-4}	0.13000×10^{-4}	N.S.	
Total	13	0.11939×10^{-3}	0.91840×10^{-5}		
"Remaining" protein fraction [TN - (LIS + NPN) mg N/mg meat, dry weight basis]					
Regression	5	0.90399×10^{-3}	0.18078×10^{-3}	14.9834^{a}	$F_{5,8(0.0007)}=14.98$
Residual	8	0.96532×10^{-4}	0.12066×10^{-4}	S.	
Lack of fit	4	0.35491×10^{-4}	0.08873×10^{-4}	0.5814	$F_{4,4(0.20)}=2.48$
Pure error	4	0.61041×10^{-4}	0.15260×10^{-4}	N.S.	
Total	13	0.10005×10^{-2}	0.76963×10^{-4}		

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leqslant 0.10$).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P \leqslant 0.20$ was used during exploratory work and then $P \leqslant 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

Table C.4. Pork loin roasts' analysis of variance of photovolt filters, calculated Commission Internationale de l'Eclairage (C.I.E.) (English: International Commission on Illumination) values, chromaticity coordinates, Hunter L, aL, and bL values, hue angles, and saturation indices for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
Photovolt filter, amber					
Regression	5	4.0789	0.8158	0.1441[a]	$F_{5,7(0.20)}=1.97$
Residual	8	39.6238	5.6605	N.S.	
Lack of fit	4	7.2519	2.4173	0.2987	$F_{3,4(0.20)}=2.48$[d]
Pure error	4	32.3720	8.0930	N.S.	
Total	13	43.7027	3.6419		
Photovolt filter, blue					
Regression	5	11.8424	2.3685	0.5909[a]	$F_{5,7(0.20)}=1.97$
Residual	8	28.0576	4.0082	N.S.	
Lack of fit	4	4.9256	1.6419	0.2839	$F_{3,4(0.20)}=2.48$
Pure error	4	23.1320	5.7830	N.S.	
Total	13	39.9000	3.3250		
Photovolt filter, green					
Regression	5	6.1624	1.2325	0.1371[a]	$F_{5,7(0.20)}=1.97$
Residual	8	62.9345	8.9906	N.S.	
Lack of fit	4	26.2145	8.7382	0.9519	$F_{3,4(0.20)}=2.48$
Pure error	4	36.7200	9.1800	N.S.	
Total	13	69.0969	5.7581		
C.I.E. X-value					
Regression	5	4.2144	0.8429	0.1680[a]	$F_{5,7(0.20)}=1.97$
Residual	8	35.1338	5.0191	N.S.	
Lack of fit	4	6.4283	2.1428	0.2986	$F_{3,4(0.20)}=2.48$
Pure error	4	28.7055	7.1764	N.S.	
Total	13	39.3482	3.2790		
C.I.E. Y-value					
Regression	5	6.1624	1.2325	0.1371[a]	$F_{5,7(0.20)}=1.97$
Residual	8	62.9345	8.9906	N.S.	
Lack of fit	4	26.2145	8.7382	0.9519	$F_{3,4(0.20)}=2.48$
Pure error	4	36.7200	9.1800	N.S.	
Total	13	69.0969	5.7581		

Table C.4. Pork loin roasts' analysis of variance of photovolt filters, calculated Commission Internationale de l'Eclairage (C.I.E.) (English: International Commission on Illumination) values, chromaticity coordinates, Hunter L, aL, and bL values, hue angles, and saturation indices for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
C.I.E. Z-value					
Regression	5	16.5109	3.3022	0.5909[a]	$F_{5,7(0.20)}=1.97$
Residual	8	39.1168	5.5881	N.S.	
Lack of fit	4	6.8581	2.2860	0.2835	$F_{3,4(0.20)}=2.48$[d]
Pure error	4	32.2587	8.0647	N.S.	
Total	13	55.6277	4.6356		
Chromaticity coordinate, x					
Regression	5	0.57223×10^{-4}	0.11445×10^{-4}	0.4318[a]	$F_{5,7(0.20)}=1.97$
Residual	8	0.18555×10^{-3}	0.26507×10^{-4}	N.S.	
Lack of fit	4	0.84300×10^{-4}	0.28100×10^{-4}	1.1106	$F_{3,4(0.443)}=1.11$
Pure error	4	0.10120×10^{-3}	0.25300×10^{-4}	N.S.	
Total	13	0.24277×10^{-3}	0.20231×10^{-4}		
Chromaticity coordinate,y					
Regression	5	0.18383×10^{-3}	0.36767×10^{-4}	0.4483[b]	$F_{5,3(0.20)}=2.97$
Residual	8	0.27524×10^{-3}	0.39320×10^{-4}	N.S.	
Lack of fit	4	0.24600×10^{-3}	0.82014×10^{-4}	11.2348	$F_{3,4(0.02)}=11.24$
Pure error	4	0.02920×10^{-3}	0.73000×10^{-5}	S.	
Total	13	0.45908×10^{-3}	0.38256×10^{-4}		
Chromaticity coordinate, z					
Regression	5	0.32424×10^{-3}	0.64848×10^{-4}	4.6287[a]	$F_{5,7(0.0348)}=4.63$
Residual	8	0.98069×10^{-4}	0.14010×10^{-4}	S.	
Lack of fit	4	0.59269×10^{-4}	0.19756×10^{-4}	2.0367	$F_{3,4(0.20)}=2.48$
Pure error	4	0.38800×10^{-4}	0.97000×10^{-5}	N.S.	
Total	13	0.42231×10^{-3}	0.35192×10^{-4}		
Hunter L-value					
Regression	5	4.0546	0.8109	0.1456[a]	$F_{5,7(0.20)}=1.97$
Residual	8	38.9743	5.5678	N.S.	
Lack of fit	4	16.4058	5.4686	0.9692	$F_{3,4(0.20)}=2.48$
Pure error	4	22.5685	5.6421	N.S.	
Total	13	43.0289	3.5857		

Table C.4. Pork loin roasts' analysis of variance of photovolt filters, calculated Commission Internationale de l'Eclairage (C.I.E.) (English: International Commission on Illumination) values, chromaticity coordinates, Hunter L, aL, and bL values, hue angles, and saturation indices for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
Hunter aL-value					
Regression	5	13.4187	2.6837	0.1263[b]	$F_{5,3(0.20)}=2.97$
Residual	8	84.2119	12.0303	N.S.	
Lack of fit	4	63.7322	21.2441	4.1493	$F_{3,4(0.101)}=4.15$
Pure error	4	20.4797	5.1199	S.	
Total	13	97.6306	8.1359		
Hunter bL-value					
Regression	5	10.7446	2.1489	0.7285[b]	$F_{5,3(0.20)}=2.97$
Residual	8	9.8423	1.4060	N.S.	
Lack of fit	4	8.8496	2.9498	11.8859	$F_{3,4(0.018)}=11.89$
Pure error	4	0.9927	0.2482	S.	
Total	13	20.5869	1.7156		
Hue angle (tan bL/aL)					
Regression	5	120.8220	24.1644	0.6115[b]	$F_{5,3(0.20)}=2.97$
Residual	8	131.9430	18.8490	N.S.	
Lack of fit	4	118.5485	39.5162	11.8007	$F_{3,4(0.018)}=11.80$
Pure error	4	13.3945	3.3486	S.	
Total	13	252.7650	21.0637		
Saturation Index ((aL**2 + bL)**0.5)					
Regression	5	19.3152	3.8630	0.3167[b]	$F_{5,3(0.20)}=2.97$
Residual	8	38.0394	5.4342	N.S.	
Lack of fit	4	36.5888	12.1963	33.6310	$F_{3,4(0.0027)}=33.63$
Pure error	4	1.4506	0.3625	S.	
Total	13	57.3546	4.7796		

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a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leq 0.10$).

b = Lack of Fit Mean Square is the error term (F_{calc} = Regression Mean/Lack of Fit Mean Square).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P \leq 0.20$ was used during exploratory work and then $P \leq 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

Table C.5. Pork loin roasts' analysis of variance of selected sensory quality characteristics for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Tenderness (1 = very tough; 5 = very tender)					
Regression	5	3.128	0.626	1.4656^{a}	$F_{5,7(0.20)}=1.97$
Residual	8	2.988	0.427	N.S.	
Lack of fit	3	1.720	0.573	1.8090	$F_{3,4(0.20)}=2.48^{d}$
Pure error	4	1.268	0.317	N.S.	
Total	13	6.117	0.510		
Flavor (1 = no meaty flavor; 5 = very pronounced meaty flavor)					
Regression	5	0.194	0.039	0.3925^{a}	$F_{5,7(0.20)}=1.97$
Residual	8	0.693	0.099	N.S.	
Lack of fit	3	0.113	0.038	0.2605	$F_{3,4(0.20)}=2.48$
Pure error	4	0.580	0.145	N.S.	
Total	13	0.888	0.074		
Doneness (1 = very undercooked; 5 = very overcooked)					
Regression	5	0.670	0.134	0.7426^{a}	$F_{5,7(0.20)}=1.97$
Residual	8	1.263	0.180	N.S.	
Lack of fit	3	0.523	0.174	0.9416	$F_{3,4(0.20)}=2.48$
Pure error	4	0.740	0.185	N.S.	
Total	13	1.932	0.161		
Juiciness (1 = very dry; 5 = very juicy)					
Regression	5	2.306	0.461	2.8708^{a}	$F_{5,7(0.1009)}=2.87$
Residual	8	1.125	0.161	S.	
Lack of fit	3	0.485	0.162	1.0100	$F_{3,4(0.20)}=2.48$
Pure error	4	0.640	0.160	N.S.	
Total	13	3.431	0.286		
Color (1 = rosy red; 5 = grey brown)					
Regression	5	0.969	0.194	0.8965^{a}	$F_{5,7(0.20)}=1.97$
Residual	8	1.514	0.216	N.S.	
Lack of fit	3	0.774	0.258	1.3941	$F_{3,4(0.20)}=2.48$
Pure error	4	0.740	0.185	N.S.	
Total	13	2.483	0.207		

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leqslant 0.10$).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P \leqslant 0.20$ was used during exploratory work and then $P \leqslant 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

Table C.6. Lamb loin roasts' analysis of variance of initial weights, cooking loss data, heating rates, and cooking times for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Initial weight (g). (Used as a "dummy variable" to check on regression and analysis of variance results.)					
Run	1	109.6	109.6	0.0242^{b} N.S.	$F_{1,6(0.20)}=2.07$
Regression (CT*ET)	5	13104.5	2620.9	0.5776^{b} N.S.	$F_{5,6(0.20)}=2.08$
Run*Regression	5	2733.2	554.6	0.1222^{b} N.S.	$F_{5,6(0.20)}=2.08$
Residual	13	38724.8	2766.1	——	——
Lack of fit	6	27226.8	4537.8	2.7626	$F_{6,7(0.1049)}=2.76$
Pure error	7	11498.0	1642.6	S.	——
Total	24	66004.3	2750.2	——	——
Heating rate (°C/g)					
Run	1	0.00015×10^{-2}	0.00150×10^{-3}	0.0021^{b} N.S.	$F_{1,6(0.20)}=2.07$
Regression (CT*ET)	5	0.01300	0.26000×10^{-2}	3.5724^{b} S.	$F_{5,6(0.0764)}=3.57$
Run*Regression	5	0.05652×10^{-2}	0.11304×10^{-3}	0.1553^{b} N.S.	$F_{5,6(0.20)}=2.08$
Residual	13	0.63458×10^{-2}	0.48814×10^{-3}	——	——
Lack of fit	6	0.43668×10^{-2}	0.72780×10^{-3}	2.5744	$F_{6,7(0.1209)}=2.57$
Pure error	7	0.19790×10^{-2}	0.28272×10^{-3}	S.	——
Total	24	0.02372	0.98828×10^{-3}	——	——

Table C.6. Lamb loin roasts' analysis of variance of initial weights, cooking loss data, heating rates, and cooking times for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Heating rate (°C/min)					
Run	1	0.00003	0.00003	0.0011^{b} N.S.	$F_{1,6(0.20)}=2.07$
Regression (CT*ET)	5	0.50548	0.10110	3.6273^{b} S.	$F_{5,6(0.0741)}$ $=3.6273$
Run*Regression	5	0.02055	0.00411	0.1475^{b} N.S.	$F_{5,6(0.20)}=2.08$
Residual	13	0.22780	0.01752	——	———
Lack of fit	6	0.16727	0.00028	3.2232 S.	$F_{6,7(0.0756)}=3.22$
Pure error	7	0.06053	0.00865	——	———
Total	24	0.80660	0.33608	——	———
Cooking loss (total cooking loss, %)					
Run	1	0.23	0.23	0.0545^{a} N.S.	$F_{1,13(0.20)}=1.82$
Regression (CT*ET)	5	857.78	171.56	40.6218^{a} S.	$F_{5,13(0.00)}=40.62$
Run*Regression	5	20.24	4.05	0.9587^{a} N.S.	$F_{5,13(0.20)}=1.72$
Residual	13	54.90	4.22	——	———
Lack of fit	6	34.13	5.69	1.9168	$F_{6,7(0.20)}=1.96$
Pure error	7	20.77	2.97	N.S.	———
Total	24	1023.21	42.63	——	———

Table C.6. Lamb loin roasts' analysis of variance of initial weights, cooking loss data, heating rates, and cooking times for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Cooking loss (drip loss, %)					
Run	1	0.06	0.06	0.0193[a] N.S.	$F_{1,13(0.20)}=1.82$
Regression (CT*ET)	5	179.14	35.83	11.9112[a] S.	$F_{5,13(0.0002)}$ $=11.91^{d}$
Run*Regression	5	20.97	4.19	1.3943[a] N.S.	$F_{5,13(0.2894)}=1.39$
Residual	13	39.10	3.01	----	------
Lack of fit	6	11.83	1.97	0.5060	$F_{6,7(0.20)}=1.96$
Pure error	7	27.27	3.90	N.S.	------
Total	24	256.72	10.70	----	------
Cooking loss (evaporation loss, %)					
Run	1	0.52	0.52	0.1481[a] N.S.	$F_{1,13(0.20)}=1.82$
Regression (CT*ET)	5	273.04	54.61	15.5574[a] S.	$F_{5,13(0.00)}=15.56$
Run*Regression	5	17.42	3.48	0.9925[a] N.S.	$F_{5,13(0.20)}=1.72$
Residual	13	45.63	3.51	----	------
Lack of fit	6	19.92	3.32	0.9036	$F_{6,7(0.20)}=1.96$
Pure error	7	25.72	3.67	N.S.	------
Total	24	367.58	15.32	----	------

Table C.6. Lamb loin roasts' analysis of variance of initial weights, cooking loss data, heating rates, and cooking times for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Cooking time (min).					
Run	1	1.12	1.12	0.0152^{b} N.S.	$F_{1,6(0.20)}=2.07$
Regression (CT*ET)	5	3430.96	686.19	9.2813^{b} S.	$F_{5,6(0.0086)}=9.28^{d}$
Run*Regression	5	18.70	3.74	0.0506^{b} N.S.	$F_{5,6(0.20)}=2.08$
Residual	13	595.32	45.79	—	—
Lack of fit	6	443.59	73.93	3.4108 S.	$F_{6,7(0.0667)}=3.41$
Pure error	7	151.73	21.68	—	—
Total	24	4062.54	169.27	—	—
Heating rate (°C/g/min).					
Run	1	0.56800×10^{-8}	0.56800×10^{-8}	0.0074^{b} N.S.	$F_{1,6(0.20)}=2.07$
Regression (CT*ET)	5	0.12427×10^{-5}	0.24800×10^{-6}	0.3223^{b} N.S.	$F_{5,6(0.20)}=2.08$
Run*Regression	5	0.40660×10^{-6}	0.81320×10^{-7}	0.1060^{b} N.S.	$F_{5,6(0.20)}=2.08$
Residual	13	0.63329×10^{-5}	0.48714×10^{-6}	—	—
Lack of fit	6	0.460287×10^{-5}	0.76714×10^{-6}	3.1033 S.	$F_{6,7(0.0821)}=3.10$
Pure error	7	0.17300×10^{-5}	0.24720×10^{-6}	—	—
Total	24	0.91199×10^{-5}	0.37999×10^{-6}	—	—

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leqslant 0.10$).
b = Lack of Fit Mean Square is the error term (F_{calc} = Regression Mean/Lack of Fit Mean Square) ($P \leqslant 0.10$)
c = Number in parentheses = alpha-value denoting level of significance.
d = $P \leqslant 0.20$ was used during exploratory work and then $P \leqslant 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

Table C.7. Lamb loin roasts' analysis of variance of expressible moisture index (EMI), percent total moisture, proteolytic enzyme values, cooking data, heating rates, cooking times, and enzyme weight for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
Expressible moisture index (EMI)					
Regression	5	0.01363	0.00267	5.0692[a]	$F_{5,7(0.0278)}$ =5.07
Residual	7	0.00369	0.00053	S.	
Lack of fit	3	0.00131	0.00044	0.7349	$F_{3,4(0.20)}$=2.48[d]
Pure error	4	0.00238	0.00059	N.S.	
Total	12	0.01705	0.00142		
Percent total moisture (% TM)					
Regression	5	48.32	9.66	3.4086[a]	$F_{5,7(0.0704)}$ =3.41
Residual	7	19.84	2.84	S.	
Lack of fit	3	- 0.02[f]	- 0.00[f]	- 0.0011	$F_{3,4(0.20)}$=2.48
Pure error	4	19.86	4.96	N.S.	
Total	12	68.16	5.68		
Proteolytic enzyme activity (at 0°C)					
Regression	5	0.04930	0.00986	2.3419[a]	$F_{5,7(0.1489)}$ =2.34
Residual	7	0.02947	0.00421	N.S.	
Lack of fit	3	0.00603	0.00201	0.3431	$F_{3,4(0.20)}$=2.48
Pure error	4	0.02344	0.00586	N.S.	
Total	12	0.07877	0.00656		
Proteolytic enzyme activity (at 37°C/g)					
Regression	5	0.05549	0.01110	2.31124[a]	$F_{5,7(0.1525)}$ =2.31
Residual	7	0.03361	0.00480	N.S.	
Lack of fit	3	0.00736	0.00245	0.3739	$F_{3,4(0.20)}$=2.48
Pure error	4	0.02625	0.00656	N.S.	
Total	12	0.08910	0.00742		
Proteolytic enzyme activity difference [(37 - 0)°C]					
Regression	5	0.18637×10^{-3}	0.37273×10^{-4}	1.5562[a]	$F_{5,7(0.20)}$=1.97
Residual	7	0.16763×10^{-3}	0.23948×10^{-4}	N.S.	
Lack of fit	3	0.07443×10^{-3}	0.24811×10^{-4}	1.0648	$F_{3,4(0.20)}$=2.48
Pure error	4	0.09320×10^{-3}	0.23300×10^{-4}	N.S.	
Total	12	0.35400×10^{-3}	0.29500×10^{-4}		

Table C.7. Lamb loin roasts' analysis of variance of expressible moisture index (EMI), percent total moisture, proteolytic enzyme values, cooking data, heating rates, cooking times, and enzyme weight for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
pH of meat and redistilled water slurry					
Regression	5	0.0560	0.0119	2.0690[b]	$F_{5,4(0.2505)}$ =2.07
Residual	7	0.0248	0.0035	N.S.	
Lack of fit	3	0.0173	0.0058	3.0784	$F_{3,4(0.02)}$=2.48[d]
Pure error	4	0.0075	0.0019	S.	
Total	12	0.0843	0.0070		
Warner-Bratzler shear values (kg/1.27 cm core)					
Regression	5	1.9930	0.3985	1.1464[a]	$F_{5,7(0.20)}$=1.97
Residual	7	2.4338	0.3477	N.S.	
Lack of fit	3	1.0772	0.3591	1.0588	$F_{3,4(0.02)}$=2.48
Pure error	4	1.3566	0.3391	N.S.	
Total	12	4.4268	0.3689		
Enzyme weight (g). (Used as a "dummy" variable to check on regression and analysis of variance results.)					
Regression	5	0.01049	0.00210	0.6320[a]	$F_{5,7(0.20)}$=1.97
Residual	7	0.02323	0.00332	N.S.	
Lack of fit	3	0.01486	0.00495	2.3638	$F_{3,4(0.20)}$=2.48
Pure error	4	0.00838	0.00209	N.S.	
Total	12	0.03372	0.00281		

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leqslant 0.10$).

b = Lack of Fit Mean Square is the error term (F_{calc} = Regression Mean Square/Lack of Fit Mean Square) ($P \leqslant 0.10$).

c = Number in parentheses = alpha-value denoting level of significance

d = $P \leqslant 0.20$ was used during exploratory work and then $P \leqslant 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

f = Due to large variability found between the center point observations' cooking time, these values appeared to be negative and so could not be used. Regression Mean Square/Residual Mean Square, therefore, had to be used for F_{calc}.

Table C.8. Lamb loin roast: analysis of variance of total nitrogen, low ionic strength (LIS) protein solubility extract, non-protein (NPN) extract, "sarcoplasmic" protein fraction, and "remaining" protein fraction for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Total nitrogen (TN/mg meat, wet weight basis)					
Regression	5	0.21443×10^{-3}	0.42887×10^{-4}	4.1513[a]	$F_{5,6(0.0562)}=4.15$
Residual	6	0.61985×10^{-4}	0.10331×10^{-4}	S.	
Lack of fit	2	0.32580×10^{-4}	0.16290×10^{-4}	2.2160	$F_{2,4(0.20)}=2.47^{d}$
Pure error	4	0.29405×10^{-4}	0.73513×10^{-5}	N.S.	
Total	11	0.27642×10^{-3}	0.25129×10^{-4}		
Total nitrogen (% TN, wet weight basis)					
Regression	5	2.14433	0.42887	4.1513[a]	$F_{5,6(0.0562)}=4.15$
Residual	6	0.61985	0.10331	S.	
Lack of fit	2	0.32580	0.16290	2.2160	$F_{2,4(0.20)}=2.47$
Pure error	4	0.29405	0.07351	N.S.	
Total	11	2.76419	0.25129		
Low ionic strength (LIS) soluble protein fraction (mg N/mg meat, wet weight basis)					
Regression	5	0.82726×10^{-5}	0.16545×10^{-5}	2.4683[a]	$F_{5,6(0.1510)}=2.47$
Residual	6	0.40218×10^{-5}	0.67031×10^{-6}	N.S.	
Lack of fit	2	0.10874×10^{-5}	0.54369×10^{-6}	0.7411	$F_{2,4(0.20)}=2.47$
Pure error	4	0.29345×10^{-5}	0.73362×10^{-6}	N.S.	
Total	11	0.12294×10^{-4}	0.11177×10^{-5}		
Non-protein nitrogen (NPN) extract (mg N/mg meat, wet weight basis)					
Regression	5	0.65068×10^{-5}	0.13014×10^{-6}	0.3448[a]	$F_{5,6(0.20)}=2.08$
Residual	6	0.22648×10^{-5}	0.37746×10^{-6}	N.S.	
Lack of fit	2	0.99840×10^{-6}	0.49924×10^{-6}	1.5770	$F_{2,4(0.20)}=2.47$
Pure error	4	0.12663×10^{-5}	0.31657×10^{-6}	N.S.	
Total	11	0.29154×10^{-5}	0.26504×10^{-6}		
"Sarcoplasmic" protein fraction = [(LIS-NPN) mg N/mg meat, wet weight basis]					
Regression	5	0.66946×10^{-5}	0.13389×10^{-5}	1.4482[a]	$F_{5,6(0.20)}=2.08$
Residual	6	0.55473×10^{-4}	0.92454×10^{-6}	N.S.	
Lack of fit	2	0.29984×10^{-5}	0.14992×10^{-5}	2.3527	$F_{2,4(0.3296)}=2.47$
Pure error	4	0.25488×10^{-5}	0.63721×10^{-6}	N.S.	
Total	11	0.12242×10^{-4}	0.11129×10^{-5}		

Table C.8. Lamb loin roast: analysis of variance of total nitrogen, low ionic strength (LIS) protein solubility extract, non-protein (NPN) extract, "sarcoplasmic" protein fraction, and "remaining" protein fraction for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
"Remaining" protein fraction [TN - (LIS) + NPN) mg N/mg meat, wet weight basis]					
Regression	5	0.21714×10^{-3}	0.43429×10^{-4}	3.3089[b]	$F_{5,2(0.2482)}=3.31$
Residual	6	0.45379×10^{-4}	0.75632×10^{-5}	N.S.	
Lack of fit	2	0.26250×10^{-4}	0.13125×10^{-4}	2.7444	$F_{2,4(0.20)}=2.47$[d]
Pure error	4	0.19130×10^{-4}	0.47824×10^{-5}	S.	
Total	11	0.26252×10^{-3}	0.23866×10^{-4}		
Total nitrogen (TN/mg meat, dry weight basis)					
Regression	5	0.58868×10^{-3}	0.11774×10^{-3}	1.1571[a]	$F_{5,6(0.20)}=2.08$
Residual	6	0.61050×10^{-3}	0.10175×10^{-3}	N.S.	
Lack of fit	2	0.23203×10^{-3}	0.11602×10^{-3}	1.2262	$F_{2,4(0.20)}=2.47$
Pure error	4	0.37846×10^{-3}	0.94616×10^{-4}	N.S.	
Total	11	0.11992×10^{-2}	0.10902×10^{-3}		
Total nitrogen (% TN, dry weight basis)					
Regression	5	5.89	1.18	1.1571[a]	$F_{5,6(0.20)}=2.08$
Residual	6	6.10	1.02	N.S.	
Lack of fit	2	2.32	1.16	1.2262	$F_{2,4(0.20)}=2.47$
Pure error	4	3.78	0.95	N.S.	
Total	11	11.99	1.09		
Low ionic strength (LIS) soluble protein fraction (mg N/mg meat, dry weight basis)					
Regression	5	0.84748×10^{-4}	0.16950×10^{-4}	2.0873[a]	$F_{5,6(0.1983)}=2.09$
Residual	6	0.48723×10^{-3}	0.81205×10^{-5}	N.S.	
Lack of fit	2	0.11590×10^{-4}	0.57949×10^{-5}	0.6241	$F_{2,4(0.20)}=2.47$
Pure error	4	0.37139×10^{-4}	0.92848×10^{-5}	N.S.	
Total	11	0.13347×10^{-3}	0.12134×10^{-4}		
Non-protein nitrogen (NPN) extract (mg N/mg meat, dry weight basis)					
Regression	5	0.81412×10^{-5}	0.16282×10^{-5}	0.4215[a]	$F_{5,6(0.20)}=2.08$
Residual	6	0.23176×10^{-4}	0.38627×10^{-5}	N.S.	
Lack of fit	2	0.88099×10^{-5}	0.44050×10^{-5}	1.2265	$F_{2,4(0.20)}=2.47$
Pure error	4	0.14366×10^{-4}	0.35915×10^{-4}	N.S.	
Total	11	0.31317×10^{-4}	0.28402×10^{-5}		

Table C.8. Lamb loin roast: analysis of variance of total nitrogen, low ionic strength (LIS) protein solubility extract, non-protein (NPN) extract, "sarcoplasmic" protein fraction, and "remaining" protein fraction for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	$F_{table}{}^{c}$
"Sarcoplasmic" protein fraction [(LIS - NPN) mg N/mg meat, dry weight basis)]					
Regression	5	0.74107×10^{-4}	0.14821×10^{-3}	1.5928^{a}	$F_{5,6(0.2921)}=1.59$
Residual	6	0.55830×10^{-4}	0.93050×10^{-5}	N.S.	
Lack of fit	2	0.28003×10^{-4}	0.14002×10^{-4}	2.0127	$F_{2,4(0.20)}=2.47^{d}$
Pure error	4	0.27827×10^{-4}	0.69567×10^{-5}	N.S.	
Total	11	0.12994×10^{-3}	0.11812×10^{-4}		
"Remaining" protein fraction [TN - (LIS + NPN) mg N/mg meat, dry weight basis]					
Regression	5	0.81771×10^{-3}	0.16354×10^{-3}	1.7557^{b}	$F_{5,2(0.20)}=4.28$
Residual	6	0.33730×10^{-3}	0.56217×10^{-4}	N.S.	
Lack of fit	2	0.18630×10^{-3}	0.93148×10^{-3}	2.4674	$F_{2,4(0.2004)}=2.47$
Pure error	4	0.15101×10^{-3}	0.37752×10^{-4}	N.S.	
Total	11	0.11550×10^{-2}	0.10500×10^{-3}		

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leq 0.10$).

b = Lack of Fit Mean Square used as the error term (F_{calc} = Regression Mean Square/Lack of Fit Mean Square) ($P \leq 0.10$).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P \leq 0.20$ were used during exploratory work and then $P \leq 0.20$ were used for evaluating significance of the MSLF/MSPE's F_{calc} value.

Table C.9. Lamb loin roasts' analysis of variance of photovolt filters, calculated Commission Internationale de l'Eclairage (C.I.E.) (English: International Commission on Illumination) values, chromaticity coordinates, Hunter L, aL, and bL values, hue angles, and saturation indices for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Photovolt filter, amber					
Regression	5	17.1557	3.4311	2.760[a]	$F_{5,7(0.1091)}=2.76$
Residual	7	8.7012	1.2430	N.S.	
Lack of fit	3	2.4092	0.8031	0.511	$F_{3,4(0.20)}=2.48^{d}$
Pure error	4	6.2920	1.5730	N.S.	
Total	12	25.8569	2.1547		
Photovolt filter, blue					
Regression	5	13.8046	2.7609	1.840[a]	$F_{5,7(0.20)}=1.97$
Residual	7	10.5031	1.5004	N.S.	
Lack of fit	3	2.9511	0.9837	0.521	$F_{3,4(0.20)}=2.48$
Pure error	4	7.5520	1.8880	N.S.	
Total	12	24.3077	2.0256		
Photovolt filter, green					
Regression	5	12.2650	2.4530	1.117[a]	$F_{5,7(0.20)}=1.97$
Residual	7	15.3673	2.1953	N.S.	
Lack of fit	3	6.0593	2.0198	0.868	$F_{3,4(0.20)}=2.48$
Pure error	4	9.3080	2.3270	N.S.	
Total	12	27.6323	2.3027		
C.I.E. X-value					
Regression	5	11.3456	2.2691	1.854[a]	$F_{5,7(0.20)}=1.97$
Residual	7	8.5697	1.2242	N.S.	
Lack of fit	3	2.3826	0.7942	0.514	$F_{3,4(0.20)}=2.48$
Pure error	4	6.1871	1.5468	N.S.	
Total	12	19.9153	1.6596		
C.I.E. Y-value					
Regression	5	12.2650	2.4530	1.117[a]	$F_{5,7(0.20)}=1.97$
Residual	7	15.3673	2.1953	N.S.	
Lack of fit	3	6.0593	2.0198	0.868	$F_{3,4(0.20)}=2.48$
Pure error	4	9.3080	2.3270	N.S.	
Total	12	27.6323	2.3027		

Table C.9. Lamb loin roasts' analysis of variance of photovolt filters, calculated Commission Internationale de l'Eclairage (C.I.E.) (English: International Commission on Illumination) values, chromaticity coordinates, Hunter L, aL, and bL values, hue angles, and saturation indices for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
C.I.E. Z-value					
Regression	5	19.2525	3.8505	1.8396[a]	$F_{5,7(0.20)}=1.97$
Residual	7	14.6514	2.0931	N.S.	
Lack of fit	3	4.1033	1.3678	0.5187	$F_{3,4(0.20)}=2.48$[d]
Pure error	4	10.5481	2.6370	N.S.	
Total	12	33.9039	2.8253		
Chromaticity coordinate, x					
Regression	5	0.22630×10^{-2}	0.45260×10^{-3}	8.4237[a]	$F_{5,7(0.0071)}=8.42$
Residual	7	0.37610×10^{-3}	0.53729×10^{-4}	S.	
Lack of fit	3	0.21330×10^{-3}	0.71100×10^{-4}	1.7469	$F_{3,4(0.20)}=2.48$
Pure error	4	0.16280×10^{-3}	0.40700×10^{-4}	N.S.	
Total	12	0.26391×10^{-2}	0.21992×10^{-3}		
Chromaticity coordinate, y					
Regression	5	0.21905×10^{-3}	0.43810×10^{-4}	0.8679[b]	$F_{5,3(0.20)}=2.97$
Residual	7	0.20464×10^{-3}	0.29234×10^{-4}	N.S.	
Lack of fit	3	0.15144×10^{-3}	0.50480×10^{-4}	3.7955	$F_{3,4(0.1152)}=3.80$
Pure error	4	0.53200×10^{-4}	0.13300×10^{-4}	S.	
Total	12	0.42369×10^{-3}	0.35308×10^{-4}		
Chromaticity coordinate, z					
Regression	5	0.13687×10^{-2}	0.27374×10^{-3}	12.2555[a]	$F_{5,7(0.0024)}=12.26$
Residual	7	0.15635×10^{-3}	0.22336×10^{-4}	S.	
Lack of fit	3	0.55153×10^{-4}	0.18384×10^{-4}	0.7266	$F_{3,4(0.20)}=2.48$
Pure error	4	0.10120×10^{-3}	0.25300×10^{-4}	N.S.	
Total	12	0.15251×10^{-2}	0.12709×10^{-3}		
Hunter L-value					
Regression	5	15.0228	3.0046	1.1597[a]	$F_{5,7(0.20)}=1.97$
Residual	7	18.1357	2.5908	N.S.	
Lack of fit	3	7.4506	2.4835	0.9297	$F_{3,4(0.20)}=2.48$
Pure error	4	10.6851	2.6713	N.S.	
Total	12	33.1585	2.7632		

Table C.9. Lamb loin roasts' analysis of variance of photovolt filters, calculated Commission Internationale de l'Eclairage (C.I.E.) (English: International Commission on Illumination) values, chromaticity coordinates, Hunter L, aL, and bL values, hue angles, and saturation indices for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
Hunter aL-value					
Regression	5	196.5380	39.3077	3.7508[a]	$F_{5,3(0.1528)}=3.75$
Residual	7	47.8465	6.8352	N.S.	
Lack of fit	3	31.4098	10.4699	2.5479	$F_{3,4(0.20)}=2.48$[d]
Pure error	4	16.4367	4.1092	S.	
Total	12	244.3850	20.3654		
Hunter bL-value					
Regression	5	4.2382	0.8476	1.7269[b]	$F_{5,3(0.20)}=2.97$
Residual	7	1.8097	0.2585	N.S.	
Lack of fit	3	1.4724	0.4908	5.8199	$F_{3,4(0.0610)}=5.82$
Pure error	4	0.3373	0.0843	S.	
Total	12	6.0479	0.5040		
Hue angle (tan bL/aL					
Regression	5	19.3446	3.8689	1.2908[a]	$F_{5,7(0.20)}=1.97$
Residual	7	20.9812	2.9973	N.S.	
Lack of fit	3	1.1130	0.3710	0.0747	$F_{3,4(0.02)}=2.48$
Pure error	4	19.8682	4.9670	N.S.	
Total	12	40.3258	3.3605		
Saturation index ((aL**2 + bL**2)**0.5)					
Regression	5	71.2417	14.2483	6.0848[b]	$F_{5,3(0.0840)}=6.09$
Residual	7	7.7900	1.1129	S.	
Lack of fit	3	7.0249	2.3416	12.2418	$F_{3,4(0.0175)}=12.24$
Pure error	4	0.7651	0.1913	S.	
Total	12	79.0317	6.5860		

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leq 0.10$).

b = Lack of Fit Mean Square is the error term (F_{calc} = Regression Mean/ Lack of Fit Mean Square) ($P \leq 0.10$).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P \leq 0.20$ was used during exploratory work and then $P \leq 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

Table C.10. Lamb loin roasts' analysis of variance of selected sensory quality characteristics for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
Tenderness (1 = very tough; 5 = very tender)					
Regression	5	0.793	0.159	0.2145[a]	$F_{5,7(0.20)}=1.97$
Residual	7	5.179	0.740	N.S.	
Lack of fit	3	1.948	0.649	0.8032	$F_{3,4(0.20)}=2.48$[d]
Pure error	4	3.23	0.808	N.S.	
Total	12	5.972	0.498		
Flavor (1 = no meaty flavor; 5 = very pronounced meaty flavor)					
Regression	5	1.756	0.351	4.906[b]	$F_{5,3(0.1104)}=4.91$
Residual	7	0.327	0.047	N.S.	
Lack of fit	3	0.215	0.072	2.556	$F_{3,4(0.1933)}=2.56$
Pure error	4	0.112	0.028	S.	
Total	12	2.083	0.174		
Doneness (1 = very undercooked; 5 = very overcooked)					
Regression	5	1.732	0.346	8.9426[a]	$F_{5,7(0.006)}=8.94$
Residual	7	0.271	0.039	S.	
Lack of fit	3	0.143	0.048	1.490	$F_{3,4(0.20)}=2.48$
Pure error	4	0.128	0.032	N.S.	
Total	12	2.003	0.167		
Juiciness (1 = very dry; 5 = very juicy)					
Regression	5	4.594	0.919	4.8016[b]	$F_{5,3(0.1134)}=4.80$
Residual	7	0.726	0.104	N.S.	
Lack of fit	3	0.574	0.191	5.0356	$F_{3,4(0.0792)}=5.04$
Pure error	4	0.152	0.038	S.	
Total	12	5.320	0.443		
Color (1 = rosy red; 5 = brownish grey)					
Regression	5	8.251	1.650	3.2275[a]	$F_{5,7(0.0792)}=3.22$
Residual	7	3.579	0.511	S.	
Lack of fit	3	0.879	0.293	0.4342	$F_{3,4(0.20)}=2.48$
Pure error	4	2.70	0.675	N.S.	
Total	12	11.831	0.986		

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a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leq 0.10$).

b = Lack of Fit Mean Square is the error term (F_{calc} = Regression Mean/Lack of Fit Mean Square ($P \leq 0.10$).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P < 0.20$ was used during exploratory work and then $P \leq 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

Table C.11. Turkey breast roasts' analysis of variance table for initial weights, cooking loss data, heating rates, and cooking times for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
<u>Initial weight (g). (Used as a "dummy variable" to check on regression and analysis of variance results.)</u>					
Run	1	35255.0	35255.0	0.4971[a] N.S.	$F_{1,14(0.20)}=1.81$
Regression (CT*ET)	5	611137.9	122227.6	1.7234[a] N.S.	$F_{5,14(0.20)}=1.70^{d}$
Run*Regression	5	81147.0	16229.4	0.2288[a] N.S.	$F_{5,14(0.20)}=1.70$
Residual	14	992944.0	70924.6	0.2222 N.S.	$F_{6,8(0.20)}=1.88$
Lack of fit	6	141824.0	23637.3	——	——
Pure error	8	851120.0	106390.0	——	——
Total	25	169005.0	——	——	——
<u>Heating rate (°C/g)</u>					
Run	1	0.10300×10^{-7}	0.10300×10^{-7}	0.0048[a] N.S.	$F_{1,14(0.20)}=1.81$
Regression (CT*ET)	5	0.30241×10^{-4}	0.06048×10^{-4}	2.8371[a] S.	$F_{5,14(0.0567)}=2.84$
Run*Regression	5	0.02586×10^{-4}	0.51728×10^{-6}	0.2427[a] N.S.	$F_{5,14(0.20)}=1.70$
Residual	14	0.29835×10^{-4}	0.21311×10^{-5}	——	——
Lack of fit	6	0.12295×10^{-4}	0.20492×10^{-4}	——	——
Pure error	8	0.17540×10^{-4}	0.21925×10^{-5}	0.9346 N.S.	$F_{6,8(0.20)}=1.88$
Total	25	0.62578×10^{-4}	——	——	——

Table C.11. Turkey breast roasts' analysis of variance table for initial weights, cooking loss data, heating rates, and cooking times for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Heating rate (°C/min)					
Run	1	0.0	0.0	0.0000^{b} N.S.	$F_{1,6(0.20)}=2.07$
Regression (CT*ET)	5	0.39448	0.07890	10.9381^{b} S.	$F_{5,6(0.0056)}=10.94$
Run*Regression	5	0.03529	0.00706	0.9784^{b} N.S.	$F_{5,6(0.20)}=2.08$
Residual	14	0.06092	0.00435	——	———
Lack of fit	6	0.04328	0.00721	——	———
Pure error	8	0.01764	0.00220	3.2715 S.	$F_{6,8(0.0625)}=2.67$
Total	25	0.49368	——	——	———
Cooking loss (total cooking loss, %)					
Run	1	0.41	0.41	0.0180^{b} N.S.	$F_{1,6(0.20)}=2.07$
Regression (CT*ET)	5	376.01	75.20	3.2860^{b} S.	$F_{5,6(0.0899)}=3.29$
Run*Regression	5	43.86	8.77	6.3833^{b} N.S.	$F_{5,6(0.20)}=2.08$
Residual	14	193.08	13.79	——	———
Lack of fit	6	137.31	22.88	——	———
Pure error	8	55.77	6.97	3.2827 S.	$F_{6,8(0.0620)}=2.67$
Total	25	620.77	——	——	———

Table C.11. Turkey breast roasts' analysis of variance table for initial weights, cooking loss data, heating rates, and cooking times for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Cooking loss (drip loss, %)					
Run	1	6.23	6.23	1.1991^{a} N.S.	$F_{1,14(0.20)}=1.81$
Regression (CT*ET)	5	39.27	7.85	1.5120^{a} N.S.	$F_{5,14(0.2484)}=1.70^{d}$
Run*Regression	5	7.84	1.57	0.3017^{a} N.S.	$F_{5,14(0.20)}=1.70$
Residual	14	72.73	5.19	----	------
Lack of fit	6	32.98	5.50	----	------
Pure error	8	39.75	4.97	1.1064 N.S.	$F_{6,8(0.20)}=1.88$
Total	25	124.944	----	----	------
Cooking loss (evaporation loss, %)					
Run	1	2.80	2.80	0.1421^{a} N.S.	$F_{1,14(0.20)}=1.81$
Regression (CT*ET)	5	360.23	72.04	3.6626^{a} S.	$F_{5,14(0.025)}=3.66$
Run*Regression	5	71.23	14.25	0.7242^{a} N.S.	$F_{5,14(0.20)}=1.70$
Residual	14	275.38	19.67	----	------
Lack of fit	6	84.25	14.04	----	------
Pure error	8	191.14	23.89	0.5877 N.S.	$F_{6,8(0.20)}=1.88$
Total	25	711.48	----	----	------

Table C.11. Turkey breast roasts' analysis of variance table for initial weights, cooking loss data, heating rates, and cooking times for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Cooking time (min).					
Run	1	181.40	181.40	0.8522[a] N.S.	$F_{1,14(0.20)}=1.81$
Regression (CT*ET)	5	28914.01	5782.80	27.1659[a] S.	$F_{5,14(0.0000)}$ =27.17
Run*Regression	5	2532.30	506.46	2.3792[a] N.S.	$F_{5,14(0.10)}=2.31$
Residual	14	2980.21	212.87	----	------
Lack of fit	6	1601.86	266.98	----	------
Pure error	8	1378.35	172.29	1.5495 N.S.	$F_{6,8(0.20)}=1.88$
Total	25	34744.90	----	----	------
Heating rate (°C/g/min).					
Run	1	0.00831×10^{-8}	0.000831×10^{-7}	0.2282[a] N.S.	$F_{5,14(0.20)}=1.70$
Regression (CT*ET)	5	0.24015×10^{-7}	0.48030×10^{-8}	13.1872[a] S.	$F_{5,14(0.0001)}$ =13.19
Run*Regression	5	0.24260×10^{-8}	0.00485×10^{-7}	1.3322[a] N.S.	$F_{5,14(0.20)}=1.70$
Residual	14	0.50990×10^{-8}	0.03642×10^{-8}	----	------
Lack of fit	6	0.23362×10^{-8}	0.03894×10^{-8}	----	------
Pure error	8	0.27628×10^{-8}	0.34535×10^{-9}	1.1275 N.S.	$F_{6,8(0.20)}=1.88$
Total	25	0.31786×10^{-7}	----	----	------

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leq 0.10$).
b = Lack of Fit Mean Square is the error term (F_{calc} = Regression Mean/Lack of Fit Mean Square) ($P \leq 0.10$).
c = Number in parentheses = alpha-value denoting level of significance.
d = $P \leq 0.20$ was used during exploratory work and then $P \leq 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

Table C.12. Turkey breast roasts' analysis of variance of expressible moisture index (EMI), percent total moisture, proteolytic enzyme values, cooking data, heating rates, cooking times, and enzyme weight for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
Expressible moisture index (EMI)					
Regression	5	0.00677	0.00135	0.9137[a]	$F_{5,7(0.20)}=1.97$
Residual	7	0.01038	0.00148	N.S.	
Lack of fit	3	0.00042	0.00014	0.0562	$F_{3,4(0.20)}=2.48$[d]
Pure error	4	0.00996	0.00249	N.S.	
Total	12	0.01715	0.00143		
Percent total moisture (% TM)					
Regression	5	19.71530	3.94307	0.6154[b]	$F_{5,3(0.20)}=2.97$
Residual	7	22.90630	3.27232	N.S.	
Lack of fit	3	19.22331	6.40777	6.9593	$F_{3,4(0.046)}=6.96$
Pure error	4	3.68299	0.92075	S.	
Total	12	42.62160	3.55180		
Proteolytic enzyme activity (at 0°C)					
Regression	5	0.49673×10^{-4}	0.99346×10^{-5}	2.0915[a]	$F_{5,7(0.182)}=2.09$
Residual	7	0.33250×10^{-4}	0.47500×10^{-5}	N.S.	
Lack of fit	3	0.06050×10^{-4}	0.20168×10^{-5}	0.2966	$F_{3,4(0.20)}=2.48$
Pure error	4	0.27200×10^{-4}	0.68000×10^{-5}	N.S.	
Total	12	0.82923×10^{-4}	0.69103×10^{-5}		
Proteolytic enzyme activity (at 37°C/g)					
Regression	5	0.47382×10^{-4}	0.94764×10^{-5}	0.2725[a]	$F_{5,7(0.20)}=1.97$
Residual	7	0.24339×10^{-3}	0.34770×10^{-4}	N.S.	
Lack of fit	3	8.93870×10^{-5}	2.97950×10^{-5}	0.7739	$F_{3,4(0.20)}=2.48$
Pure error	4	0.15400×10^{-3}	0.38500×10^{-4}	N.S.	
Total	12	0.29076×10^{-3}	0.24231×10^{-4}		
Proteolytic enzyme activity difference [(37 - 0)°C]					
Regression	5	0.40603×10^{-4}	0.08120×10^{-4}	0.4189[a]	$F_{5,7(0.20)}=1.97$
Residual	7	0.13570×10^{-3}	0.19386×10^{-4}	N.S.	
Lack of fit	3	0.66505×10^{-4}	0.02216×10^{-4}	1.2814	$F_{3,4(0.20)}=2.48$
Pure error	4	0.69200×10^{-4}	0.17300×10^{-4}	N.S.	
Total	12	0.17631×10^{-3}	0.14692×10^{-4}		

Table C.12. Turkey breast roasts' analysis of variance of expressible moisture index (EMI), percent total moisture, proteolytic enzyme values, cooking data, heating rates, cooking times, and enzyme weight for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
pH of meat and redistilled water slurry					
Regression	5	0.03374	0.00675	1.0959[a]	$F_{5,7(0.20)}$=1.97
Residual	7	0.04310	0.00616	N.S.	
Lack of fit	3	0.00342	0.00114	0.1148	$F_{3,4(0.20)}$=2.48[d]
Pure error	4	0.03968	0.00992	N.S.	
Total	12	0.07683	0.00640		
pH of meat slurry extract, after enzyme removal					
Regression	5	0.01448	0.00290	0.7974[a]	$F_{5,7(0.20)}$=1.97
Residual	7	0.02542	0.00363	N.S.	
Lack of fit	3	0.00690	0.00230	0.4965	$F_{3,4(0.20)}$=2.48
Pure error	4	0.01852	0.00463	N.S.	
Total	12	0.03990	0.00332		
Warner-Bratzler shear values (kg/127 mm)					
Regression	5	2.09328	0.41866	0.8461[a]	$F_{5,7(0.20)}$=1.97
Residual	7	3.46362	0.49480	N.S.	
Lack of fit	3	1.63810	0.54603	1.1964	$F_{3,4(0.20)}$=2.48
Pure error	4	1.82552	0.45638	N.S.	
Total	12	5.55690	0.46308		
Enzyme weight (g). (Used as a "dummy" variable to check on regression and analysis of variance results.)					
Regression	5	0.062449	0.012490	0.2440[a]	$F_{5,4(0.20)}$=1.97
Residual	7	0.358372	0.051196	N.S.	
Lack of fit	3	0.003755	0.001252	0.0141	$F_{3,4(0.20)}$=2.48
Pure error	4	0.354617	0.088654	N.S.	
Total	12	0.420821	0.035068		

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square ($P \leq 0.10$).

b = Lack of Fit Mean Square is the error term (F_{calc} = Regression Mean Square/Lack of Fit Mean Square) ($P \leq 0.10$).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P \leq 0.20$ was used during exploratory work and then $P \leq 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

Table C.13. Turkey breast roasts' analysis of variance of total nitrogen, low ionic strength (LIS) protein solubility extract, non-protein (NPN) extract, "sarcoplasmic" protein fraction and "remaining" protein fraction for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
Total nitrogen (TN/mg meat, wet weight basis)					
Regression	5	0.81562×10^{-4}	0.16312×10^{-4}	0.6620[b]	$F_{5,3(0.20)}=2.97$
Residual	7	0.84232×10^{-4}	0.12033×10^{-4}	N.S.	
Lack of fit	3	0.73927×10^{-5}	0.02464×10^{-4}	9.565	$F_{3,4(0.027)}=9.56$[d]
Pure error	4	0.10305×10^{-4}	0.02576×10^{-4}	S.	
Total	12	0.16579×10^{-3}	0.13816×10^{-4}		
Total nitrogen (% TN, wet weight basis)					
Regression	5	0.81562	0.16312	0.6620[b]	$F_{5,7(0.20)}=1.97$
Residual	7	0.84232	0.12033	N.S.	
Lack of fit	3	0.73927	0.24642	9.565	$F_{3,4(0.027)}=9.56$
Pure error	4	0.10305	0.02576	S.	
Total	12	1.65793	0.13816		
Low ionic strength (LIS) soluble protein fraction (mg N/mg meat, wet weight basis)					
Regression	5	0.36177×10^{-5}	0.72353×10^{-6}	1.7861[b]	$F_{5,3(0.20)}=2.97$
Residual	7	0.14555×10^{-5}	0.20793×10^{-6}	N.S.	
Lack of fit	3	0.12150×10^{-6}	0.40509×10^{-7}	6.744	$F_{3,4(0.048)}=6.74$
Pure error	4	0.24025×10^{-6}	0.60064×10^{-7}	S.	
Total	12	0.50732×10^{-5}	0.42276×10^{-6}		
Non-protein nitrogen (NPN) extract (mg N/mg meat, wet weight basis)					
Regression	5	0.17589×10^{-5}	0.35178×10^{-6}	6.847[a]	$F_{5,7(0.013)}=6.85$
Residual	7	0.35963×10^{-6}	0.51375×10^{-7}	S.	
Lack of fit	3	0.20870×10^{-7}	0.69580×10^{-8}	1.844	$F_{3,4(0.20)}=2.48$
Pure error	4	0.15088×10^{-6}	0.37721×10^{-7}	N.S.	
Total	12	0.21185×10^{-5}	0.17654×10^{-6}		
"Sarcoplasmic" protein fraction = [(LIS-NPN) mg N/mg meat, wet weight basis]					
Regression	5	0.11570×10^{-5}	0.23140×10^{-6}	4.6642[b]	$F_{5,3(0.1175)}=4.66$
Residual	7	0.16072×10^{-5}	0.22960×10^{-6}	N.S.	
Lack of fit	3	0.14883×10^{-6}	0.49612×10^{-7}	16.697	$F_{3,4(0.01)}=16.70$
Pure error	4	0.11885×10^{-6}	0.29713×10^{-7}	S.	
Total	12	0.27642×10^{-5}	0.23035×10^{-6}		

Table C.13. Turkey breast roasts' analysis of variance of total nitrogen, low ionic strength (LIS) protein solubility extract, non-protein (NPN) extract, "sarcoplasmic" protein fraction and "remaining" protein fraction for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
"Remaining" protein fraction [TN - (LIS) + NPN) mg N/mg meat, wet weight basis]					
Regression	5	0.77997 × 10^{-4}	0.15599 × 10^{-4}	0.8339[b]	$F_{5,3(0.20)}=2.97$
Residual	7	0.70639 × 10^{-4}	0.10091 × 10^{-4}	N.S.	
Lack of fit	3	0.05612 × 10^{-4}	0.01871 × 10^{-4}	5.154	$F_{3,4(0.074)}=5.15$[d]
Pure error	4	0.14517 × 10^{-4}	0.03629 × 10^{-4}	S.	
Total	12	0.14864 × 10^{-3}	0.12386 × 10^{-4}		
Total nitrogen (TN/mg meat, dry weight basis)					
Regression	5	0.68378 × 10^{-3}	0.13676 × 10^{-3}	3.569[a]	$F_{5,7(0.064)}=3.57$
Residual	7	0.26817 × 10^{-3}	0.38310 × 10^{-4}	S.	
Lack of fit	3	0.13919 × 10^{-4}	0.46398 × 10^{-5}	1.439	$F_{3,4(0.20)}=2.48$
Pure error	4	0.12897 × 10^{-3}	0.32243 × 10^{-4}	N.S.	
Total	12	0.95194 × 10^{-3}	0.79329 × 10^{-4}		
Total nitrogen (% TN, dry weight basis)					
Regression	5	6.83776	1.36755	3.569[a]	$F_{5,7(0.064)}=3.57$
Residual	7	2.68167	0.38310	S.	
Lack of fit	3	1.39100	0.46398	1.4389	$F_{3,4(0.20)}=2.48$
Error	4	1.28973	0.32243	N.S.	
Total	12	9.51942	0.79329		
Low ionic strength (LIS) soluble protein fraction (mg N/mg meat, dry weight basis)					
Regression	5	0.29353 × 10^{-4}	0.58706 × 10^{-5}	5.5964[a]	$F_{5,7(0.022)}=5.60$
Residual	7	0.73430 × 10^{-5}	0.10490 × 10^{-5}	S.	
Lack of fit	3	0.25624 × 10^{-5}	0.08510 × 10^{-5}	0.7146	$F_{3,4(0.20)}=2.48$
Pure error	4	0.47807 × 10^{-5}	0.11952 × 10^{-5}	N.S.	
Total	12	0.36696 × 10^{-4}	0.30580 × 10^{-5}		
Non-protein nitrogen (NPN) extract (mg N/mg meat, dry weight basis)					
Regression	5	0.14499 × 10^{-4}	0.28997 × 10^{-5}	2.592[a]	$F_{5,7(0.123)}=2.59$
Residual	7	0.78323 × 10^{-5}	0.11189 × 10^{-5}	N.S.	
Lack of fit	3	0.42120 × 10^{-6}	0.01404 × 10^{-5}	1.5516	$F_{3,4(0.20)}=2.48$
Pure error	4	0.36198 × 10^{-5}	0.09050 × 10^{-5}	N.S.	
Total	12	0.22331 × 10^{-4}	0.18609 × 10^{-5}		

Table C.13. Turkey breast roasts' analysis of variance of total nitrogen, low ionic strength (LIS) protein solubility extract, non-protein (NPN) extract, "sarcoplasmic" protein fraction and "remaining" protein fraction for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
"Sarcoplasmic" protein fraction [(LIS - NPN) mg N/mg meat, dry weight basis]					
Regression	5	0.11189×10^{-4}	0.22378×10^{-5}	0.5163[b]	$F_{5,7(0.20)}=1.97$
Residual	7	0.14105×10^{-4}	0.20150×10^{-5}	N.S.	
Lack of fit	3	0.01300×10^{-4}	0.43340×10^{-5}	15.751	$F_{3,4(0.011)}=15.75$[d]
Pure error	4	0.01101×10^{-4}	0.02752×10^{-5}	S.	
Total	12	0.25295×10^{-4}	0.21078×10^{-5}		
"Remaining" protein fraction [TN - (LIS + NPN) mg N/mg meat, dry weight basis]					
Regression	5	0.71536×10^{-3}	0.14307×10^{-3}	3.970[a]	$F_{5,7(0.05)}=3.97$
Residual	7	0.25228×10^{-3}	0.36040×10^{-4}	S.	
Lack of fit	3	0.01346×10^{-3}	0.44877×10^{-5}	1.525	$F_{3,4(0.20)}=2.48$
Pure error	4	0.11764×10^{-3}	0.29413×10^{-4}	N.S.	
Total	12	0.96763×10^{-3}	0.80636×10^{-4}		

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leqslant 0.10$).

b = Lack of Fit Mean Square used as the error term (F_{calc} = Regression Mean Square/Lack of Fit Mean Square) ($P \leqslant 0.10$).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P \leqslant 0.20$ was used during exploratory work and then $P \leqslant 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

Table C.14. Roast turkey breasts' analysis of variance of selected sensory quality characteristics for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
Tenderness (1 = very tough; 5 = very tender)					
Regression	5	1.988	0.398	1.6516[a]	$F_{5,7(0.20)}=1.97$
Residual	7	1.685	0.241	N.S.	
Lack of fit	3	1.057	0.352	2.2436	$F_{3,4(0.226)}=2.24$[d]
Pure error	4	0.628	0.157	N.S.	
Total	12	3.672	0.306		
Flavor (1 = no meaty flavor; 5 = very pronounced meaty flavor)					
Regression	5	0.348	0.070	0.738[a]	$F_{5,7(0.20)}=1.97$
Residual	7	0.661	0.094	N.S.	
Lack of fit	3	0.429	0.143	2.4648	$F_{3,4(0.202)}=2.46$
Pure error	4	0.232	0.058	N.S.	
Total	12	1.009	0.084		
Doneness (1 = very undercooked; 5 = very overcooked)					
Regression	5	0.548	0.110	0.9227[a]	$F_{5,7(0.20)}=1.97$
Residual	7	0.832	0.119	N.S.	
Lack of fit	3	0.332	0.111	0.8848	$F_{3,4(0.20)}=2.48$
Pure error	4	0.500	0.125	N.S.	
Total	12	1.380	0.115		
Juiciness (1 = very dry; 5 = very juicy)					
Regression	5	1.519	0.304	0.8264[a]	$F_{5,7(0.20)}=1.97$
Residual	7	2.573	0.368	N.S.	
Lack of fit	3	1.533	0.511	1.9657	$F_{3,4(0.20)}=2.48$
Pure error	4	1.040	0.260	N.S.	
Total	12	4.092	0.341		

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leqslant 0.10$).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P \leqslant 0.20$ was used during exploratory work and then $P \leqslant 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

Table C.14. Turkey thigh roasts' analysis of variance of expressible moisture index (EMI), percent total moisture, proteolytic enzyme values, cooking data, heating rates, cooking times, and enzyme weight for the central composite rotatable design (CCRD).[e]

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
Expressible moisture index (EMI)					
Regression	5	0.04124	0.00825	2.1279[a]	$F_{5,7(0.1763)}$ =2.13
Residual	7	0.02713	0.00388	N.S.	
Lack of fit	3	Neg. value[f]	Neg. value[f]	———	———
Pure error	4	0.03267	0.00817		
Total	12	0.06838	0.00570		
Percent total moisture (% TM)					
Regression	5	41.65	8.33	1.7498[a]	$F_{5,7(0.20)}$=1.97
Residual	7	33.32	4.76	N.S.	
Lack of fit	3	5.96	1.99	0.2907	$F_{3,4(0.20)}$=2.48
Pure error	4	27.359	6.84	N.S.	
Total	12	74.97	6.25		
Proteolytic enzyme activity (at 0°C)					
Regression	5	0.00757	0.00151	0.9152[a]	$F_{5,7(0.20)}$=1.97
Residual	7	0.01158	0.00165	N.S.	
Lack of fit	3	0.00562	0.00187	1.2566	$F_{3,4(0.20)}$=2.48
Pure error	4	0.00596	0.00149	N.S.	
Total	12	0.01914	0.00160		
Proteolytic enzyme activity (at 37°C/g)					
Regression	5	0.00802	0.00160	0.9363[a]	$F_{5,7(0.20)}$=1.97
Residual	7	0.01199	0.00171	N.S.	
Lack of fit	3	0.00655	0.00218	1.6063	$F_{3,4(0.20)}$=2.48
Pure error	4	0.00544	0.00136	N.S.	
Total	12	0.02001	0.00167		
Proteolytic enzyme activity difference [(37 - 0)°C]					
Regression	5	0.22136×10^{-3}	0.44273×10^{-4}	0.7458[a]	$F_{5,7(0.20)}$=1.97
Residual	7	0.41556×10^{-3}	0.59366×10^{-4}	N.S.	
Lack of fit	3	0.06476×10^{-3}	0.21586×10^{-4}	0.2461	$F_{3,4(0.20)}$=2.48
Pure error	4	0.35080×10^{-3}	0.87700×10^{-4}	N.S.	
Total	12	0.63692×10^{-3}	0.53077×10^{-4}		

Table C.15. Turkey thigh roasts' analysis of variance of expressible moisture index (EMI), percent total moisture, proteolytic enzyme values, cooking data, heating rates, cooking times, and enzyme weight for the central composite rotatable design (CCRD).[e] (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
pH of meat and redistilled water slurry					
Regression	5	0.02746	0.00549	0.1589[a]	$F_{5,7(0.20)}=1.97$
Residual	7	0.24191	0.03456	N.S.	
Lack of fit	3	0.10123	0.03374	0.9594	$F_{3,4(0.20)}=2.48$[d]
Pure error	4	0.14068	0.03517	N.S.	
Total	12	0.26937	0.02245		
pH of meat slurry extract, after enzyme removal					
Regression	5	0.06397	0.01279	0.5974[a]	$F_{5,7(0.20)}=1.97$
Residual	7	0.14992	0.02142	N.S.	
Lack of fit	3	0.05984	0.01995	0.8858	$F_{3,4(0.020)}=2.48$
Pure error	4	0.09008	0.02252	N.S.	
Total	12	0.21389	0.01782		
Warner-Bratzler shear values (kg/127 mm)					
Regression	5	2.67866	0.53573	2.0243[a]	$F_{5,7(0.1918)}$ =2.02
Residual	7	1.85259	0.26466	N.S.	
Lack of fit	3	0.50066	0.16688	0.4938	$F_{3,4(0.020)}=2.48$
Pure error	4	1.35193	0.33798	N.S.	
Total	12	4.53125	0.37760		
Enzyme weight (g). (Used as a "dummy" variable to check on regression and analysis of variance results.)					
Regression	5	0.00357	0.00071	0.5990[a]	$F_{5,4(0.20)}=1.97$
Residual	7	0.00835	0.00119	N.S.	
Lack of fit	3	0.00349	0.00116	0.9546	$F_{3,4(0.20)}=2.48$
Pure error	4	0.00487	0.00122	N.S.	
Total	12	0.01193	0.00099		

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a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leq 0.10$).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P \leq 0.20$ was used during exploratory work and then $P \leq 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

e = Cooking time was used instead of endpoint temperature for the second Y-variable, as turkey halves were roasted and breast endpoint temperature was monitored more accurately than the thigh endpoint temperature.

f = Due to large variability found between the center point observations' cooking time, these values appeared to be negative and so could not be used. Regression Mean Square/Residual Mean Square, therefore had to be used for F_{calc}.

Table C.16. Turkey thigh roasts' analysis of variance table of total nitrogen, low ionic strength (LIS) protein solubility extract, non-protein (NPN) extract, "sarcoplasmic" protein fraction, and "remaining" protein fraction for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
Total nitrogen (TN/mg meat, wet weight basis)					
Regression	5	0.06662×10^{-3}	0.13325×10^{-4}	0.6169[a]	$F_{5,6(0.694)}=0.62$
Residual	6	0.12961×10^{-3}	0.21602×10^{-4}	N.S.	
Lack of fit	2	Neg. value[f]	Neg. value[f]	-----	-----
Pure error	4	0.13657×10^{-3}	0.34143×10^{-4}		
Total	11	0.19624×10^{-3}	0.17840×10^{-4}		
Total nitrogen (% TN, wet weight basis)					
Regression	5	0.66626	0.13325	0.6169[a]	$F_{5,6(0.694)}=0.62$
Residual	6	1.29610	0.21602	N.S.	
Lack of fit	2	Neg. value[f]	Neg. value[f]	-----	-----
Pure error	4	1.36573	0.34143		
Total	11	1.96236	0.17840		
Low ionic strength (LIS) soluble protein fraction (mg N/mg meat, wet weight basis)					
Regression	5	0.28573×10^{-5}	0.57146×10^{-6}	1.8155[a]	$F_{5,6(0.24)}=1.82$
Residual	6	0.18885×10^{-5}	0.31475×10^{-6}	N.S.	
Lack of fit	2	0.05667×10^{-5}	0.18889×10^{-6}	0.5716	$F_{2,4(0.20)}=2.47$
Pure error	4	0.13218×10^{-5}	0.33045×10^{-6}	N.S.	
Total	11	0.47458×10^{-5}	0.43144×10^{-6}		
Non-protein nitrogen (NPN) extract (mg N/mg meat, wet weight basis)					
Regression	5	0.39105×10^{-5}	0.78209×10^{-6}	1.4585[a]	$F_{5,6(0.20)}=2.08$
Residual	6	0.32173×10^{-5}	0.53622×10^{-6}	N.S.	
Lack of fit	2	0.18597×10^{-5}	0.61989×10^{-6}	1.8262	$F_{2,4(0.20)}=2.47$
Pure error	4	0.13576×10^{-5}	0.33941×10^{-6}	N.S.	
Total	11	0.71278×10^{-5}	0.64798×10^{-6}		
"Sarcoplasmic" protein fraction = [(LIS-NPN) mg N/mg meat, wet weight basis]					
Regression	5	0.92086×10^{-5}	0.18417×10^{-5}	1.5815[b]	$F_{5,6(0.20)}=2.08$
Residual	6	0.40437×10^{-5}	0.06740×10^{-5}	N.S.	
Lack of fit	2	0.34936×10^{-5}	0.11645×10^{-5}	8.4672	$F_{2,4(0.036)}=8.47$
Pure error	4	0.05502×10^{-5}	0.01375×10^{-5}	S.	
Total	11	0.13252×10^{-4}	0.12048×10^{-5}		

Table C.16. Turkey thigh roasts' analysis of variance table of total nitrogen, low ionic strength (LIS) protein solubility extract, non-protein (NPN) extract, "sarcoplasmic" protein fraction, and "remaining" protein fraction for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
"Remaining" protein fraction [TN - (LIS + NPN) mg N/mg meat, wet weight basis]					
Regression	5	0.09004×10^{-3}	0.18007×10^{-4}	1.0635[a]	$F_{5,6(0.20)}=2.08$
Residual	6	0.10159×10^{-3}	0.16932×10^{-4}	N.S.	
Lack of fit	2	Neg. value[f]	Neg. value[f]	——	——
Pure error	4	0.10842×10^{-3}	0.27105×10^{-4}		
Total	11	0.19163×10^{-3}	0.17420×10^{-4}		
Total nitrogen (TN/mg meat, dry weight basis)					
Regression	5	0.14228×10^{-2}	0.28456×10^{-3}	0.8966[a]	$F_{5,6(0.20)}=2.08$
Residual	6	0.19042×10^{-2}	0.31737×10^{-3}	N.S.	
Lack of fit	2	Neg. value[f]	Neg. value[f]	——	——
Pure error	4	0.20399×10^{-2}	0.50999×10^{-3}		
Total	11	0.33270×10^{-2}	0.30246×10^{-3}		
Total nitrogen (% TN, dry weight basis)					
Regression	5	14.22810	2.84562	0.8966[a]	$F_{5,6(0.20)}=2.08$
Residual	6	19.04190	3.17365	N.S.	
Lack of fit	2	Neg. value[f]	Neg.value[f]	——	——
Pure error	4	20.39970	5.09992		
Total	11	33.27000	3.02455		
Low ionic strength (LIS) soluble protein fraction (mg N/mg meat, dry weight basis)					
Regression	5	0.15834×10^{-4}	0.31669×10^{-5}	0.1900[b]	$F_{5,6(0.20)}=2.08$
Residual	6	0.22076×10^{-4}	0.36793×10^{-5}	N.S.	
Lack of fit	2	0.33330×10^{-4}	1.66650×10^{-5}	3.5566	$F_{2,4(0.1296)}=3.56$
Pure error	4	0.18743×10^{-4}	0.46857×10^{-5}	S.	
Total	11	0.37910×10^{-4}	0.34464×10^{-5}		
Non-protein nitrogen (NPN) extract (mg N/mg meat, dry weight basis)					
Regression	5	0.29074×10^{-4}	0.58148×10^{-5}	0.9704[a]	$F_{5,6(0.20)}=2.08$
Residual	6	0.35954×10^{-4}	0.59924×10^{-5}	N.S.	
Lack of fit	2	0.19282×10^{-4}	0.96409×10^{-5}	2.3143	$F_{2,4(0.20)}=2.47$
Pure error	4	0.16663×10^{-4}	0.41658×10^{-5}	N.S.	
Total	11	0.65029×10^{-4}	0.59117×10^{-5}		

Table C.16. Turkey thigh roasts' analysis of variance table of total nitrogen, low ionic strength (LIS) protein solubility extract, non-protein (NPN) extract, "sarcoplasmic" protein fraction, and "remaining" protein fraction for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
"Sarcoplasmic" protein fraction [(LIS - NPN) mg N/mg meat, dry weight basis)]					
Regression	5	0.60079×10^{-4}	0.01202×10^{-5}	1.0229^{b}	$F_{5,2(0.20)}=4.28$
Residual	6	0.27930×10^{-4}	0.46555×10^{-5}	N.S.	
Lack of fit	2	0.23495×10^{-4}	0.01175×10^{-5}	10.5898	$F_{2,4(0.20)}=10.59^{d}$
Pure error	4	0.04437×10^{-4}	0.11093×10^{-5}	S.	
Total	11	0.88012×10^{-4}	0.80011×10^{-5}		
"Remaining" protein fraction [TN - (LIS + NPN) mg N/mg meat, dry weight basis]					
Regression	5	0.15548×10^{-2}	0.31097×10^{-3}	1.4300^{a}	$F_{5,6(0.20)}=2.08$
Residual	6	0.13047×10^{-2}	0.21745×10^{-3}	N.S.	
Lack of fit	2	Neg. value[f]	Neg. value[f]	----	----
Pure error	4	0.15080×10^{-2}	0.37700×10^{-3}		
Total	11	0.28596×10^{-2}	0.25996×10^{-3}		

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leq 0.10$).

b = Lack of Fit Mean Square used as the error term (F_{calc} = Regression Mean Square/Lack of Fit Mean Square) ($P \leq 0.10$).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P \leq 0.20$ was used during exploratory work and then $P \leq 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

e = Cooking time was used instead of endpoint temperature for the second Y-variable, as turkey halves were roasted and breast endpoint temperature was monitored more accurately then the thigh endpoint temperature

f = Due to large variability found between the center point observations' cooking time, these values appeared to be negative and so could not be used. Regression Mean Square/Residual Mean Square, therefore, had to be used for F_{calc}.

Table C.17. Roast turkey thighs' analysis of variance of selected sensory quality characteristics for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
Tenderness (1 = very tough; 5 = very tender)					
Regression	5	1.141	0.228	1.6844[a]	$F_{5,7(0.20)}=1.97$
Residual	7	0.948	0.135	N.S.	
Lack of fit	3	0.296	0.099	0.6059	$F_{3,4(0.20)}=2.48$[d]
Pure error	4	0.652	0.163	N.S.	
Total	12	2.089	0.174		
Flavor (1 = no meaty flavor; 5 = very pronounced meaty flavor)					
Regression	5	0.414	0.083	1.493[b]	$F_{5,3(0.20)}=2.97$
Residual	7	0.234	0.033	N.S.	
Lack of fit	3	0.166	0.055	3.258	$F_{3,4(0.142)}=3.26$
Pure error	4	0.068	0.017	S.	
Total	12	0.648	0.054		
Doneness (1 = very undercooked; 5 = very overcooked)					
Regression	5	0.593	0.119	1.0966[a]	$F_{5,7(0.20)}=1.97$
Residual	7	0.757	0.108	N.S.	
Lack of fit	3	0.265	0.088	0.7170	$F_{3,4(0.20)}=2.48$
Pure error	4	0.492	0.123	N.S.	
Total	12	1.349	0.112		
Juiciness (1 = very dry; 5 = very juicy)					
Regression	5	1.235	0.247	7.7815[a]	$F_{5,7(0.009)}=7.78$
Residual	7	0.222	0.032	S.	
Lack of fit	3	0.074	0.025	0.6680	$F_{3,4(0.20)}=2.48$
Pure error	4	0.148	0.037	N.S.	
Total	12	1.457	0.121		

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leq 0.10$).

b = Lack of Fit Mean Square is the error term (F_{calc} = Regression Mean/Lack of Fit Mean Square) ($P \leq 0.10$).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P \leq 0.20$ was used during exploratory work and then $P \leq 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

Table C.18. Beef control roasts' analysis of variance of initial weights, cooking loss data, heating rates, and cooking times for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Initial weight (g). (Used as a "dummy variable" to check on regression and analysis of variance results.)					
Regression	5	14.9	3.0	0.2255^{a}	$F_{5,7(0.20)}=1.97$
Residual	7	92.7	13.2	N.S.	
Lack of fit	3	42.7	14.2	1.1400	$F_{3,4(0.20)}=2.48^{d}$
Pure error	4	50.0	12.5	N.S.	
Total	12	107.6	9.0		
Heating rate (°C/g)					
Regression	5	0.12288	0.02458	15.6079^{b}	$F_{5,3(0.0234)}$ =15.60
Residual	7	0.00645	0.00092	S.	
Lack of fit	3	0.00472	0.00157	3.6398	$F_{3,4(0.1221)}$ =3.64
Pure error	4	0.00173	0.00043	S.	
Total	12	0.12933	0.10777		
Heating rate (°C/min)					
Regression	5	10.87220	2.17445	2.3155^{b}	$F_{5,3(0.2605)}$ =2.32
Residual	7	2.86792	0.40970	N.S.	
Lack of fit	3	2.81720	0.93907	74.0617	$F_{3,4(0.0006)}$ =74.06
Pure error	4	0.05072	0.01268	S.	
Total	12	13.74020	1.14501		
Cooking loss (total cooking loss, %)					
Regression	5	943.73	188.75	5.4535^{b}	$F_{5,3(0.0967)}$ =5.45
Residual	7	116.12	16.59	S.	
Lack of fit	3	103.83	34.61	11.2650	$F_{3,4(0.0202)}$ =11.26
Pure error	4	12.29	3.07	S.	
Total	12	1059.85	88.32		
Cooking loss (drip loss, %)					
Regression	5	6.84	1.37	0.8104^{a}	$F_{5,7(0.20)}=1.97$
Residual	7	11.81	1.69	N.S.	
Lack of fit	3	6.19	2.06	1.4659	$F_{3,4(0.20)}=2.48$
Pure error	4	5.63	1.41	N.S.	
Total	12	18.65	1.55		

Table C.18. Beef control roasts' analysis of variance of initial weights, cooking loss data, heating rates, and cooking times for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Cooking loss (evaporation loss, %)					
Regression	5	1063.40	212.68	5.8548[b]	$F_{5,3}(0.0883)$ =5.85
Residual	7	114.83	16.40	S.	
Lack of fit	3	108.98	36.32	24.8206	$F_{3,4}(0.0048)$ =24.82
Pure error	4	5.85	1.46	S.	
Total	12	1178.23	98.18		
Cooking time (min).					
Regression	5	0.13402×10^{-2}	0.26805×10^{-3}	2.1436[b]	$F_{5,3}(0.2816)$ =2.14
Residual	7	0.38853×10^{-3}	0.55504×10^{-4}	N.S.	
Lack of fit	3	0.37513×10^{-3}	0.12504×10^{-3}	37.3290	$F_{3,4}(0.0022)$ =37.33
Pure error	4	0.13399×10^{-4}	0.33498×10^{-5}	S.	
Total	12	0.17288×10^{-2}	0.14406×10^{-3}		
Heating rate (°C/g/min).					
Regression	5	5193.79	1038.76	18.1830[b]	$F_{5,3}(0.0188)$ =18.18
Residual	7	183.81	26.26	S.	
Lack of fit	3	171.38	57.13	18.3698	$F_{3,4}(0.0084)$ =18.37
Pure error	4	12.42	3.11	S.	
Total	12	5377.60	448.13		

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leqslant 0.10$).

b = Lack of Fit Mean Square is the error term (F_{calc} = Regression Mean Square/Lack of Fit Mean Square) ($P \leqslant 0.10$).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P \leqslant 0.20$ was used during exploratory work and then $P \leqslant 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

Table C.19. Beef control roasts' analysis of variance of expressible moisture index (EMI), percent total moisture, proteolytic enzyme values, cooking data, heating rates, cooking times, and enzyme weight for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Expressible moisture index (EMI)					
Regression	5	0.04169	0.00834	5.7241^{a}	$F_{5,7(0.0204)}=5.72$
Residual	7	0.01020	0.00146	S.	
Lack of fit	3	0.00344	0.00115	0.6795	$F_{3,4(0.20)}=2.48^{d}$
Pure error	4	0.00676	0.00169	N.S.	
Total	12	0.05189	0.00432		
Percent total moisture (% TM)					
Regression	5	159.80	31.96	2.1419^{b}	$F_{5,3(0.20)}=2.97$
Residual	7	51.20	7.31	N.S.	
Lack of fit	3	44.76	14.92	9.2728	$F_{3,4(0.0284)}=9.27$
Pure error	4	6.44	1.61	S.	
Total	12	211.00	17.58		
Proteolytic enzyme activity (at 0°C)					
Regression	5	0.23282	0.04656	0.2392^{b}	$F_{5,3(0.20)}=2.97$
Residual	7	0.06549	0.00936	N.S.	
Lack of fit	3	0.05840	0.01947	10.9840	$F_{3,4(0.0212)}=10.98$
Pure error	4	0.00709	0.00177	S.	
Total	12	0.29831	0.02486		
Proteolytic enzyme activity (at 37°C/g)					
Regression	5	0.27487	0.05497	2.4617^{b}	$F_{5,3(0.20)}=2.97$
Residual	7	0.07421	0.01060	N.S.	
Lack of fit	3	0.06699	0.02233	12.6157	$F_{3,4(0.0166)}=12.62$
Pure error	4	0.00708	0.00177	S.	
Total	12	0.34907	0.02909		
Proteolytic enzyme activity difference [(37 - 0)°C]					
Regression	5	0.19828×10^{-2}	0.39656×10^{-3}	0.2622^{b}	$F_{5,3(0.20)}=2.97$
Residual	7	0.46613×10^{-2}	0.06659×10^{-3}	N.S.	
Lack of fit	3	0.45381×10^{-2}	0.15127×10^{-3}	49.1136	$F_{3,4(0.0013)}=49.11$
Pure error	4	0.01232×10^{-2}	0.03080×10^{-3}	S.	
Total	12	0.24489×10^{-2}	0.20408×10^{-3}		

Table C.19. Beef control roasts' analysis of variance of expressible moisture index (EMI), percent total moisture, proteolytic enzyme values, cooking data, heating rates, cooking times, and enzyme weight for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
pH of meat and redistilled water slurry					
Regression	5	0.4137	0.0827	0.962[b]	$F_{5,3(0.20)}=2.97$
Residual	7	0.3569	0.0510	N.S.	
Lack of fit	3	0.2579	0.0860	3.475	$F_{3,4(0.20)}=2.48$[d]
Pure error	4	0.0990	0.0247	S.	
Total	12	0.7705	0.0642		
Enzyme weight (g). (Used as a "dummy" variable to check on regression and analysis of variance results.)					
Regression	5	0.56326	0.11265	1.039[b]	$F_{5,3(0.20)}=2.97$
Residual	7	0.33271	0.04753	N.S.	
Lack of fit	3	0.32533	0.10844	58.7	$F_{3,4(0.005)}=24.26$
Pure error	4	0.00738	0.00185	S.	
Total	12	0.89598	0.07466		

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leq 0.10$).

b = Lack of Fit Mean Square is the error term (F_{calc} = Regression Mean Square/Lack of Fit Mean Square) ($P \leq 0.10$).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P \leq 0.20$ was used during exploratory work and then $P \leq 0.10$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

Table C.20. Beef control roasts' analysis of variance of total nitrogen, low ionic strength (LIS) protein solubility extract, non-protein (NPN) extract, "sarcoplasmic" protein fraction and "remaining" protein fraction for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Total nitrogen (TN/mg meat, wet weight basis)					
Regression	5	0.15911×10^{-3}	0.31822×10^{-4}	2.1803^{a}	$F_{5,6(0.1851)}=2.08$
Residual	6	0.87571×10^{-4}	0.14595×10^{-4}	N.S.	
Lack of fit	2	0.30710×10^{-4}	0.01540×10^{-4}	0.0728	$F_{2,4(0.20)}=2.47^{d}$
Pure error	4	0.84500×10^{-4}	0.21125×10^{-4}	N.S.	
Total	11	0.24668×10^{-3}	0.22426×10^{-4}		
Total nitrogen (% TN, wet weight basis)					
Regression	5	1.59109	0.31822	2.1803^{a}	$F_{5,6(0.1851)}=2.08$
Residual	6	0.87571	0.14595	N.S.	
Lack of fit	2	0.03071	0.01536k	0.0728	$F_{2,4(0.20)}=2.47$
Pure error	4	0.84500	0.21125	N.S.	
Total	11	2.46680	0.22426		
Low ionic strength (LIS) soluble protein fraction (mg N/mg meat, wet weight basis)					
Regression	5	0.76643×10^{-5}	0.15329×10^{-5}	0.9223^{b}	$F_{5,2(0.20)}=2.97$
Residual	6	0.44049×10^{-5}	0.07342×10^{-5}	N.S.	
Lack of fit	2	0.33230×10^{-5}	0.16620×10^{-5}	6.1537	$F_{2,4(0.0602)}=6.15$
Pure error	4	0.10816×10^{-5}	0.02704×10^{-5}	S.	
Total	11	0.12069×10^{-4}	0.10972×10^{-5}		
Non-protein nitrogen (NPN) extract (mg N/mg meat, wet weight basis)					
Regression	5	0.13004×10^{-5}	0.26009×10^{-6}	0.1896^{b}	$F_{5,2(0.20)}=2.97$
Residual	6	0.30677×10^{-5}	0.51129×10^{-6}	N.S.	
Lack of fit	2	0.27440×10^{-5}	0.13720×10^{-5}	17.150	$F_{2,4(0.01)}=16.69$
Pure error	4	0.03228×10^{-5}	0.08070×10^{-6}	S.	
Total	11	0.43682×10^{-5}	0.39711×10^{-6}		
"Sarcoplasmic" protein fraction = [(LIS-NPN) mg N/mg meat, wet weight basis]					
Regression	5	0.36998×10^{-5}	0.73996×10^{-6}	2.7698^{a}	$F_{5,6(0.1213)}=3.11$
Residual	6	0.16029×10^{-5}	0.26716×10^{-6}	N.S.	
Lack of fit	2	0.05500×10^{-5}	0.27500×10^{-6}	1.0449	$F_{2,4(0.20)}=2.47$
Pure error	4	0.10527×10^{-5}	0.26318×10^{-6}	N.S.	
Total	11	0.53028×10^{-5}	0.48207×10^{-6}		

Table C.20. Beef control roasts' analysis of variance of total nitrogen, low ionic strength (LIS) protein solubility extract, non-protein (NPN) extract, "sarcoplasmic" protein fraction and "remaining" protein fraction for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
"Remaining" protein fraction [TN - (LIS) + NPN) mg N/mg meat, wet weight basis]					
Regression	5	0.18137×10^{-3}	0.36274×10^{-4}	2.1541[a]	$F_{5,6(0.10)}$3.11
Residual	6	0.10104×10^{-3}	0.16840×10^{-4}	N.S.	
Lack of fit	2	0.00644×10^{-3}	0.32180×10^{-5}	0.136	$F_{2.4(0.20)}$=2.47[d]
Pure error	4	0.09460×10^{-4}	0.23650×10^{-4}	N.S.	
Total	11	0.28241×10^{-3}	0.25674×10^{-4}		
Total nitrogen (TN/mg meat, dry weight basis)					
Regression	5	0.13798×10^{-2}	0.27597×10^{-3}	1.5223[a]	$F_{5,6(0.20)}$=2.08
Residual	6	0.10877×10^{-2}	0.18128×10^{-3}	N.S.	
Lack of fit	2	0.04325×10^{-2}	0.21620×10^{-3}	1.3199	$F_{2,4(0.20)}$=2.47
Pure error	4	0.06552×10^{-2}	0.16380×10^{-3}	N.S.	
Total	11	0.24675×10^{-2}	0.22432×10^{-3}		
Total nitrogen (% TN, dry weight basis)					
Regression	5	13.80	2.76	1.5220[a]	$F_{5,6(0.20)}$=2.08
Residual	6	10.88	1.81	N.S.	
Lack of fit	2	4.32	2.16	1.3203	$F_{2,4(0.20)}$=2.47
Pure error	4	6.55	1.64	N.S.	
Total	11	24.68	2.24		
Low ionic strength (LIS) soluble protein fraction (mg N/mg meat, dry weight basis)					
Regression	5	0.64218×10^{-4}	0.12844×10^{-4}	0.4616[b]	$F_{5,6(0.20)}$=2.97
Residual	6	0.64218×10^{-4}	0.66028×10^{-4}	N.S.	
Lack of fit	2	0.55649×10^{-4}	0.27824×10^{-4}	12.9873	$F_{2,4(0.05)}$=6.59
Pure error	4	0.08570×10^{-4}	0.02142×10^{-4}	S.	
Total	11	0.10383×10^{-3}	0.09440×10^{-4}		
Non-protein nitrogen (NPN) extract (mg N/mg meat, dry weight basis)					
Regression	5	0.20212×10^{-4}	0.40423×10^{-5}	0.9016[a]	$F_{5,2(0.20)}$=2.97
Residual	6	0.26904×10^{-4}	0.44834×10^{-5}	N.S.	
Lack of fit	2	0.24640×10^{-4}	0.12300×10^{-5}	2.1396	$F_{2,4(0.20)}$=2.47
Pure error	4	0.02230×10^{-4}	0.05749×10^{-5}	S.	
Total	11	0.47112×10^{-4}	0.42829×10^{-5}		

Table C.20. Beef control roasts' analysis of variance of total nitrogen, low ionic strength (LIS) protein solubility extract, non-protein (NPN) extract, "sarcoplasmic" protein fraction and "remaining" protein fraction for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
"Sarcoplasmic" protein fraction [(LIS - NPN) mg N/mg meat, dry weight basis)]					
Regression	5	0.23973×10^{-4}	0.47946×10^{-5}	2.6655^{a}	$F_{5,6(0.1322)}=2.67$
Residual	6	0.10834×10^{-4}	0.18056×10^{-5}	N.S.	
Lack of fit	2	0.04004×10^{-4}	0.20020×10^{-5}	1.1725	$F_{2,4(0.20)}=2.47$
Pure error	4	0.06830×10^{-4}	0.17074×10^{-5}	N.S.	
Total	11	0.34806×10^{-4}	0.31642×10^{-5}		
"Remaining" protein fraction [TN - (LIS + NPN) mg N/mg meat, dry weight basis]					
Regression	5	0.11182×10^{-2}	0.22365×10^{-3}	1.5088^{a}	$F_{5,6(0.20)}=2.08$
Residual	6	0.88940×10^{-3}	0.14823×10^{-3}	N.S.	
Lack of fit	2	0.22014×10^{-3}	0.11010×10^{-3}	0.6580	$F_{2,4(0.20)}=2.47$
Pure error	4	0.66926×10^{-3}	0.16732×10^{-3}	N.S.	
Total	11	0.20076×10^{-2}	0.18251×10^{-3}		

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leq 0.10$).

b = Lack of Fit Mean Square used as the error term (F_{calc} = Regression Mean Square/Lack of Fit Mean Square) ($P \leq 0.10$).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P \leq 0.20$ was used during exploratory work and then $P \leq 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

Table C.21. Beef treated roasts' analysis of variance table for initial weights, cooking loss data, heating rates, and cooking times for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	$F_{table}{}^{c}$
Heating rate (°C/min)					
Run	1	0.00054	0.00054	0.0050^{b} N.S.	$F_{1,6(0.20)}=1.81$
Regression (CT*ET)	5	6.28803	1.25761	11.6202^{b} S.	$F_{5,6(0.0048)}$ $=11.62$
Run*Regression	5	0.06928	0.01386	0.1280^{b} N.S.	$F_{5,6(0.20)}=2.08$
Residual	13	0.83996	0.05600	——	——
Lack of fit	6	0.64935	0.10822	4.5421	$F_{6,8(05)}=3.58^{d}$
Pure error	7	0.19062	0.02383	S.	——
Total	25	7.20710	——	——	——
Cooking loss (total cooking loss, %)					
Run	1	1.51	1.51	0.4010^{b} N.S.	$F_{1,6(0.20)}=1.81$
Regression (CT*ET)	5	1084.54	216.91	57.6056^{b} S.	$F_{5,6(0.0001)}=57.60$
Run*Regression	5	22.79	4.56	1.2105^{b} N.S.	$F_{5,6(0.20)}=2.08$
Residual	13	52.72	3.76	——	——
Lack of fit	6	31.23	5.20	1.9388	$F_{6,8(0.1897)}=1.94$
Pure error	7	21.48	2.68	S.	——
Total	25	1194.69	——	——	——

Table C.21. Beef treated roasts' analysis of variance table for initial weights, cooking loss data, heating rates, and cooking times for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Cooking loss (drip loss, %)					
Run	1	2.61	2.61	4.1363^{a} S.	$F_{1,14(0.0614)}=4.13$
Regression (CT*ET)	5	3.74	0.75	1.1870^{a} N.S.	$F_{5,14(0.3643)}=1.19^{d}$
Run*Regression	5	2.93	0.58	0.9281^{a} N.S.	$F_{5,14(0.20)}=1.81$
Residual	13	8.83	0.63	—	—
Lack of fit	6	4.58	0.76	1.4332	$F_{6,8(0.20)}=1.88$
Pure error	7	4.26	0.53	N.S.	—
Total	25	31.44	—	—	—
Cooking loss (evaporation loss, %)					
Run	1	4.23	4.23	1.2359^{a} N.S.	$F_{1,14(0.20)}=1.81$
Regression (CT*ET)	5	1065.52	213.10	62.2659^{a} S.	$F_{5,14(0.0000)}=62.26$
Run*Regression	5	21.95	4.39	1.2827^{a} N.S.	$F_{5,14(0.20)}=1.70$
Residual	13	47.92	3.42	—	—
Lack of fit	6	23.52	3.92	1.2854	$F_{6,8(0.20)}=1.88$
Pure error	7	24.40	3.05	N.S.	—
Total	25	1217.40	—	—	—

Table C.21. Beef treated roasts' analysis of variance table for initial weights, cooking loss data, heating rates, and cooking times for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Cooking time (min).					
Run	1	0.38	0.38	0.0069^{b} N.S.	$F_{1,6(0.20)}=1.81$
Regression (CT*ET)	5	7233.25	1446.65	26.2779^{b} S.	$F_{5,6(0.0005)}=26.28^{d}$
Run*Regression	5	91.42	18.28	0.3321^{b} N.S.	$F_{5,6(0.20)}=2.08$
Residual	13	402.02	28.72	——	——
Lack of fit	6	330.31	55.05	6.1417	$F_{6,8(0.0112)}=6.14$
Pure error	7	71.71	8.96	S.	——
Total	25	7727.65	——	——	——
Heating rate (°C/g/min).					
Run	1	0.62300×10^{-6}	0.62300×10^{-5}	0.3105^{b} N.S.	$F_{1,6(0.20)}=1.81$
Regression (CT*ET)	5	0.97550×10^{-3}	0.19510×10^{-3}	9.7244^{b} S.	$F_{5,6(0.01)}=8.75$
Run*Regression	5	0.14511×10^{-4}	0.29020×10^{-5}	0.1446^{b}	$F_{5,6(0.20)}=2.08$
Residual	13	0.15256×10^{-3}	0.10898×10^{-4}	——	——
Lack of fit	6	0.12038×10^{-3}	0.20063×10^{-4}	4.9871	$F_{6,8(0.025)}=4.65$
Pure error	7	0.32184×10^{-4}	0.402307×10^{-5}	S.	——
Total	25	0.11431×10^{-2}	——	——	——

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leq 0.10$).

b = Lack of Fit Mean Square is the error term (F_{calc} = Regression Mean Square/Lack of Fit Mean Square) ($P \leq 0.10$).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P \leq 0.20$ was used during exploratory work and then $P \leq 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc} value.

Table C.21. Beef treated roasts' analysis of variance table for initial weights, cooking loss data, heating rates, and cooking times for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
Initial weight (g). (Used as a "dummy variable" to check on regression and analysis of variance results.)					
Run	1	5.6	5.6	0.4025^{b} N.S.	$F_{1,6(0.20)}=1.81$
Regression (CT*ET)	5	25.5	5.1	0.3654^{b} N.S.	$F_{5,6(0.20)}=2.08^{d}$
Run*Regression	5	32.6	6.5	0.4672^{b} N.S.	$F_{5,6(0.20)}=2.08$
Residual	13	123.1	8.8	—	—
Lack of fit	6	83.9	14.0	2.8535 S.	$F_{6,7(0.0981)}=2.85$
Pure error	7	39.2	4.9		—
Total	25	196.9	—	—	—
Heating rate (°C/g)					
Run	1	0.00084	0.00084	0.5401^{b} N.S.	$F_{1,6(0.20)}=1.81$
Regression (CT*ET)	5	0.23356	0.04671	36.9414^{b} S.	$F_{5,6(0.0002)}=36.94$
Run*Regression	5	0.00294	0.00059	0.3810^{b} N.S.	$F_{5,6(0.20)}=2.08$
Residual	13	0.01400	0.00100	—	—
Lack of fit	6	0.00939	0.00156	2.7128 S.	$F_{6,8(0.0964)}=2.71$
Pure error	7	0.00461	0.00058		—
Total	25	0.26411	—	—	—

Table C.22. Beef treated roasts' analysis of variance of expressible moisture index (EMI), percent total moisture, proteolytic enzyme values, cooking data, heating rates, cooking times, and enzyme weight for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
Expressible moisture index (EMI)					
Regression	5	0.62827×10^{-2}	0.12566×10^{-2}	2.2059[b]	$F_{5,3(0.2737)}$ =2.20
Residual	7	0.24550×10^{-2}	0.35071×10^{-3}	N.S.	
Lack of fit	3	0.17090×10^{-2}	0.56965×10^{-3}	3.0544	$F_{3,4(0.1545)}$[d] =3.05
Pure error	4	0.07460×10^{-2}	0.18650×10^{-3}	S.	
Total	12	0.87377×10^{-2}	0.72814×10^{-3}		
Percent total moisture (% TM)					
Regression	5	165.41	33.08	7.8927[a]	$F_{5,7(0.0085)}$ =7.89
Residual	7	29.34	4.19	S.	
Lack of fit	3	8.30	2.77	0.5261	$F_{3,4(0.20)}$=2.48
Pure error	4	21.04	5.26	N.S.	
Total	12	194.76	16.23		
Proteolytic enzyme activity (at 0°C)(absorbance units, 520 nm)					
Regression	5	0.22696	0.04539	8.2159[b]	$F_{5,3(0.0566)}$ =8.22
Residual	7	0.01677	0.00240	S.	
Lack of fit	3	0.01657	0.00552	112.0548	$F_{3,4(0.0003)}$ =112.05
Pure error	4	0.00020	0.00005	S.	
Total	12	0.24372	0.02031		
Proteolytic enzyme activity (at 37°C/g)(absorbance units, 520 nm)					
Regression	5	0.25700	0.05140	8.6479[b]	$F_{5,3(0.0529)}$ =8.64
Residual	7	0.01832	0.00262	S.	
Lack of fit	3	0.01783	0.00594	49.1209	$F_{3,4(0.0013)}$ =49.12
Pure error	4	0.00048	0.00012	S.	
Total	12	0.27532	0.02294		
Proteolytic enzyme activity difference [(37 - 0)°C](absorbance units, 520 nm)					
Regression	5	0.98423×10^{-3}	0.19684×10^{-3}	15.19[a]	$F_{5,7(0.0012)}$ =15.19
Residual	7	0.90697×10^{-4}	0.12957×10^{-4}	S.	
Lack of fit	3	0.23497×10^{-4}	0.07832×10^{-4}	0.0466	$F_{3,4(0.20)}$=2.48
Pure error	4	0.67200×10^{-4}	0.16800×10^{-4}	N.S.	
Total	12	0.10749×10^{-2}	0.89577×10^{-4}		

Table C.22. Beef treated roasts' analysis of variance of expressible moisture index (EMI), percent total moisture, proteolytic enzyme values, cooking data, heating rates, cooking times, and enzyme weight for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
pH of meat and redistilled water slurry					
Regression	5	0.6390	0.1278	0.5911[a]	$F_{5,7(0.20)}=1.97$
Residual	7	1.5134	0.2162	N.S.	
Lack of fit	3	0.6727	0.2242	1.0668	$F_{3,4(0.02)}=2.48$[d]
Pure error	4	0.8407	0.2102	N.S.	
Total	12	2.1524	0.1794		
Warner-Bratzler shear values (kg/1.27 cm core)					
Regression	5	1.5431	0.3086	0.5701[a]	$F_{5,6(0.20)}=1.97$
Residual	6	3.2479	0.5413	N.S.	
Lack of fit	3	0.0709	0.0234	0.0446	$F_{3,3(0.02)}=2.48$
Pure error	3	3.1770	0.7942	N.S.	
Total	12	4.7910	0.4356		
Enzyme weight (g). (Used as a "dummy" variable to check on regression and analysis of variance results.)					
Regression	5	0.01842	0.00369	0.6764	$F_{5,7(0.20)}=1.97$
Residual	7	0.03814	0.00545	N.S.	
Lack of fit	3	0.01317	0.00044	0.7034	$F_{3,4(0.20)}=2.48$
Pure error	4	0.02496	0.00624	N.S.	
Total	12	0.05656	0.00471		

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leq 0.10$).

b = Lack of Fit Mean Square is the error term (F_{calc} = Regression Mean Square/Lack of Fit Mean Square) ($P \leq 0.10$).

c = Number in parentheses = alpha-value denoting level of significance.

d = $P \leq 0.20$ were used during exploratory work and then $P \leq 0.20$ were used for evaluating significance of the MSLF/MSPE's F_{calc} value.

Table C.23. Beef treated roasts' analysis of variance table of total nitrogen, low ionic strength (LIS) protein solubility extract, non-protein (NPN) extract, "sarcoplasmic" protein fraction and "remaining" protein fraction for the central composite rotatable design (CCRD).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}[c]
Total nitrogen (TN/mg meat, wet weight basis)					
Regression	5	0.21826×10^{-3}	0.43653×10^{-4}	1.5474^{b}	$F_{5,2(0.20)}=4.28$
Residual	6	0.77279×10^{-4}	0.12880×10^{-4}	N.S.	
Lack of fit	2	0.56420×10^{-4}	0.28211×10^{-4}	5.4111	$F_{2,4(0.0728)}=5.41^{d}$
Pure error	4	0.20854×10^{-4}	0.05214×10^{-4}	S.	
Total	11	0.29554×10^{-3}	0.26868×10^{-4}		
Total nitrogen (% TN, wet weight basis)					
Regression	5	2.18264	0.43653	1.5473^{b}	$F_{5,2(0.20)}=4.28$
Residual	6	0.77279	0.12880	N.S.	
Lack of fit	2	0.56426	0.28212	5.4113	$F_{2,4(0.0728)}=4.32$
Pure error	4	0.20854	0.05214	S.	
Total	11	2.95542	0.26868		
Low ionic strength (LIS) soluble protein fraction (mg N/mg meat, wet weight basis)					
Regression	5	0.57033×10^{-5}	0.11407×10^{-5}	3.0773^{a}	$F_{5,6(0.1019)}=3.07$
Residual	6	0.22240×10^{-5}	0.37066×10^{-6}	N.S.	
Lack of fit	2	0.04331×10^{-5}	0.21636×10^{-6}	0.4837	$F_{2,4(0.20)}=2.47$
Pure error	4	0.17909×10^{-5}	0.44772×10^{-6}	N.S.	
Total	11	0.79273×10^{-5}	0.72066×10^{-6}		
Non-protein nitrogen (NPN) extract (mg N/mg meat, wet weight basis)					
Regression	5	0.18201×10^{-5}	0.36402×10^{-6}	0.4858^{a}	$F_{5,6(0.20)}=2.08$
Residual	6	0.44956×10^{-5}	0.74927×10^{-6}	N.S.	
Lack of fit	2	0.10894×10^{-5}	0.54470×10^{-6}	0.6396	$F_{2,4(0.20)}=2.47$
Pure error	4	0.34062×10^{-5}	0.85156×10^{-6}	N.S.	
Total	11	0.63157×10^{-5}	0.57416×10^{-6}		
"Sarcoplasmic" protein fraction = [(LIS-NPN) mg N/mg meat, wet weight basis]					
Regression	5	0.05325×10^{-4}	0.10650×10^{-5}	0.5696^{a}	$F_{5,6(0.20)}=2.08$
Residual	6	0.11218×10^{-4}	0.18697×10^{-5}	N.S.	
Lack of fit	2	0.02499×10^{-4}	0.12497×10^{-5}	0.5733	$F_{2,4(0.20)}=2.47$
Pure error	4	0.08719×10^{-4}	0.21797×10^{-5}	N.S.	
Total	11	0.16543×10^{-4}	0.15039×10^{-5}		

Table C.23. Beef treated roasts' analysis of variance table of total nitrogen, low ionic strength (LIS) protein solubility extract, non-protein (NPN) extract, "sarcoplasmic" protein fraction and "remaining" protein fraction for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	$F_{table}{}^{c}$
"Remaining" protein fraction [TN - (LIS + NPN) mg N/mg meat, (wet weight basis)]					
Regression	5	0.30946×10^{-3}	0.61892×10^{-4}	2.4672^{b}	$F_{5,2(0.20)}=4.28$
Residual	6	0.64267×10^{-4}	0.10711×10^{-4}	N.S.	
Lack of fit	2	0.50172×10^{-4}	0.25086×10^{-4}	7.1188	$F_{2.4(0.0481)}=7.11^{d}$
Pure error	4	0.14096×10^{-4}	0.03524×10^{-4}	S.	
Total	11	0.37373×10^{-3}	0.33975×10^{-4}		
Total nitrogen (TN/mg meat, dry weight basis)					
Regression	5	0.59683×10^{-4}	0.11937×10^{-4}	0.0824^{a}	$F_{5,6(0.20)}=2.08$
Residual	6	0.86904×10^{-3}	0.14484×10^{-3}	N.S.	
Lack of fit	2	$0.19697 X 10^{-3}$	$0.98480 X 10^{-4}$	0.5861	$F_{2,4(0.20)}=2.47$
Pure error	4	0.67207×10^{-3}	0.16802×10^{-3}	N.S.	
Total	11	0.92872×10^{-3}	0.84429×10^{-4}		
Total nitrogen (% TN, dry weight basis)					
Regression	5	0.59683	0.11937	0.0824^{a}	$F_{5,6(0.20)}=2.08$
Residual	6	8.69040	1.44840	N.S.	
Lack of fit	2	1.96967	0.98480	0.5861	$F_{2,4(0.20)}=2.47$
Pure error	4	6.72073	1.68018	N.S.	
Total	11	9.28724	0.84429		
Low ionic strength (LIS) soluble protein fraction (mg N/mg meat, dry weight basis)					
Regression	5	0.10440×10^{-3}	0.20880×10^{-4}	6.9763^{a}	$F_{5,6(0.0174)}=6.98$
Residual	6	0.17958×10^{-4}	0.29930×10^{-5}	S.	
Lack of fit	2	0.50583×10^{-5}	0.25291×10^{-5}	0.7842	$F_{2,4(0.20)}=2.47$
Pure error	4	0.12900×10^{-4}	0.32250×10^{-5}	N.S.	
Total	11	0.12236×10^{-3}	0.11124×10^{-4}		
Non-protein nitrogen (NPN) extract (mg N/mg meat, dry weight basis)					
Regression	5	0.27979×10^{-4}	0.55958×10^{-5}	1.0186^{a}	$F_{5,6(0.20)}=2.08$
Residual	6	0.32961×10^{-4}	0.54935×10^{-5}	N.S.	
Lack of fit	2	0.04100×10^{-4}	0.20502×10^{-5}	0.2842	$F_{2,4(0.20)}=2.47$
Pure error	4	0.28860×10^{-4}	0.72151×10^{-5}	N.S.	
Total	11	0.60940×10^{-4}	0.55400×10^{-5}		

Table C.23. Beef treated roasts' analysis of variance table of total nitrogen, low ionic strength (LIS) protein solubility extract, non-protein (NPN) extract, "sarcoplasmic" protein fraction and "remaining" protein fraction for the central composite rotatable design (CCRD) (continued).

Source of Variation	Degrees of Freedom	Sum of Squares	Mean Squares	F_{calc}	F_{table}^{c}
"Sarcoplasmic" protein fraction [(LIS - NPN) mg N/mg meat, dry weight basis)]					
Regression	5	0.52685×10^{-4}	0.10537×10^{-4}	0.8705[a]	$F_{5,6(0.20)}=2.08$
Residual	6	0.72624×10^{-4}	0.12104×10^{-4}	N.S.	
Lack of fit	2	0.18667×10^{-4}	0.09334×10^{-4}	0.6919	$F_{2,4(0.20)}=2.47^{d}$
Pure error	4	0.53957×10^{-4}	0.13489×10^{-4}	N.S.	
Total	11	0.12531×10^{-3}	0.11392×10^{-4}		
"Remaining" protein fraction [TN - (LIS + NPN) mg N/mg meat, dry weight basis)]					
Regression	5	0.25230×10^{-3}	0.50460×10^{-4}	0.4596[a]	$F_{5,6(0.20)}=2.08$
Residual	6	0.65875×10^{-3}	0.10979×10^{-3}	N.S.	
Lack of fit	2	0.21868×10^{-3}	0.10934×10^{-4}	0.9938	$F_{2,4(0.20)}=2.47$
Pure error	4	0.44007×10^{-3}	0.11002×10^{-3}	N.S.	
Total	11	0.91105×10^{-3}	0.82823×10^{-4}		

a = Residual Mean Square used as the error term (F_{calc} = Regression Mean Square/Residual Mean Square) ($P \leq 0.10$).
b = Lack of Fit Mean Square used as the error term (F_{calc} = Regression Mean Square/Lack of Fit Mean Square) ($P \leq 0.10$).
c = Number in parentheses = alpha-value denoting level of significance.
d = $P \leq 0.20$ was used during exploratory work and then $P \leq 0.20$ was used for evaluating significance of the MSLF/MSPE's F_{calc}.

APPENDIX D

Laser Beam Computer Data Tables

Table D.1. - D.23. Laser Beam Computer Data

Table D.1. Data file (a) for pork loin roasts. Initial weights, cooking data, heating rates and cooking times, with cooking temperature-endpoint temperatures (CT-ET) for the central composite rotatable design (CCRO).

A	B	C	O	E	F(b)	G	H	I	J	K	L	M
6	282		428	79.9	1019.400	.0754	.7007	31.989	12.762	19.227	.000687	109.75
6	349		450	85.9	955.800	.0866	.9915	25.926	6.225	19.701	.001037	83.51
6	397		322	79.6	1126.200	.0680	.5056	21.302	4.733	16.569	.000449	151.50
6	496		428	92.3	1037.000	.0860	.7336	30.366	6.856	23.510	.000707	121.60
6	652		300	86.0	1088.400	.0763	.4289	24.798	5.237	19.561	.000394	193.50
6	668		375	75.9	1024.000	.0711	.5443	27.988	7.334	20.654	.000532	133.75
6	810		375	77.0	1119.700	.0661	.6727	22.810	5.439	17.371	.000601	110.00
6	866R		375	95.0	1012.700	.0928	.8545	34.670	5.224	29.446	.000844	110.00
6	919		322	92.2	1257.800	.0708	.3969	29.456	6.829	22.627	.000316	224.50
6	544	1	375	86.1	1237.700	.0671	.5832	32.528	6.149	26.379	.000471	142.50
6	614	2	375	86.6	974.400	.0858	.7379	26.622	6.076	20.546	.000757	113.30
6	843	3	375	85.9	1267.300	.0653	.5750	34.380	10.211	24.169	.000454	144.00
6	033	4	375	85.9	1104.400	.0750	.5095	31.166	5.252	25.914	.000461	162.50
6	129	5	375	85.0	1008.200	.0812	.7932	26.304	8.332	17.972	.000787	103.25

A = Species, pork.
B = Three-digit code.
C = Central composite rotatable design (CCRO) center points and further informational letters (R = repeat).
O = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Initial weight (g).
G = Heating rate (deg C/g).
H = Heating rate (deg C/min).
I = Cooking loss (total cooking loss, %).
J = Cooking loss (drip loss, %).
K = Cooking loss (evaporation loss, %).
L = Heating rate (deg C/g/min).
M = Cooking time (min).

(a) The order as given above is identical to the order used in the data file and the regression files called "STRAW6" - output from MOIST program.
No duplicate data sets are available for "double" regressions.

(b) F is a dummy variable used for checking transcribing of data and analysis of variance table results.

Table D.2. Data file (a) for pork loin roasts. Mean values of expressible moisture index (EMI), percent total moisture, proteolytic enzyme values, cooking data, heating rates, cooking times, enzyme weight used.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O(b)	P	Q	R	S	T	U	V(b)
6	282		428	79.9	.239	61.412	31.989	12.762	19.227	.0754	.7007	.000687	109.75	1019.400	.002	.005	.003	6.130	6.00	4.000	15.029
6	349		450	85.9	.325	59.852	25.926	6.225	19.701	.0866	.9915	.001037	83.51	955.800	.006	.016	.010	5.950	5.86	4.875	15.012
6	397		322	79.6	.272	64.815	21.302	4.733	16.569	.0680	.5056	.000449	151.50	1126.200	.010	.013	.003	6.120	6.04	6.775	15.043
6	496		428	92.3	.229	65.278	30.366	6.856	23.510	.0860	.7336	.000707	121.60	1037.000	.020	.031	.011	6.850	6.68	3.875	15.022
6	652		300	86.0	.340	63.128	24.798	5.237	19.561	.0763	.4289	.000394	193.50	1088.400	.004	.009	.005	6.140	6.03	5.150	15.005
6	668		375	75.9	.296	64.634	27.988	7.334	20.654	.0711	.5443	.000532	133.75	1024.000	.010	.014	.004	6.440	6.32	9.500	15.011
6	810		375	77.0	.206	66.498	22.810	5.439	17.371	.0661	.6727	.000601	110.00	1119.700	.004	.012	.008	6.040	5.95	4.150	15.021
6	866	R	375	95.0	.298	59.410	34.670	5.224	29.446	.0928	.8545	.000844	110.00	1012.700	.020	.016	-.004	6.070	6.12	4.300	15.623
6	919		322	92.2	.337	55.654	29.456	6.829	22.627	.0708	.3969	.000316	224.50	1257.800	.005	.016	.011	6.000	5.89	5.525	15.011
6	544	1	375	86.1	.283	63.610	32.528	6.149	26.379	.0671	.5832	.000471	142.50	1237.700	.002	.009	.007	5.930	5.84	3.000	15.025
6	614	2	375	86.6	.292	60.258	26.622	6.076	20.546	.0858	.7379	.000757	113.30	974.400	.005	.005	.000	6.110	5.98	4.050	15.002
6	843	3	375	85.9	.293	59.554	34.380	10.211	24.169	.0653	.5750	.000454	144.00	1267.300	.002	.017	.015	5.900	5.86	4.625	15.103
6	033	4	375	85.9	.325	59.621	31.166	5.252	25.914	.0750	.5095	.000461	162.50	1104.400	.000	.017	.017	5.990	5.90	4.575	15.033
6	129	5	375	85.0	.245	63.442	26.304	8.332	17.972	.0812	.7932	.000787	103.25	1008.200	.004	.013	.009	6.050	5.97	3.875	15.052

A = Species, pork.
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points and further informational letters (R = repeat).
D = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Expressible moisture index (EMI).
G = Percent total moisture (% TM).
H = Cooking loss (total cooking loss, %)
I = Cooking loss (drip loss, %).
J = Cooking loss (evaporation loss, %).
K = Heating rate (deg C/g).
L = Heating rate (deg C/min).
M = Heating rate (deg C/g/min).
N = Cooking time (min).
O = Initial weight (g).
P = Proteolytic enzyme activity (at 0 deg C) (absorbance at 520 nm).
Q = Proteolytic enzyme activity (at 37 deg C) (absorbance at 520 nm).
R = Proteolytic enzyme activity difference (37 deg C - 0 deg C) (absorbance at 520 nm).
S = pH of pork and redistilled water slurry.
T = pH of extract, after enzyme removal.
U = Warner-Bratzler shear values (kg/127 mm diameter core).
V = Enzyme weight (g).

(a) This is from the computer file called "PHENZ6" but the cooking loss data, heating rates, initial weight and cooking time were previously obtained from "STRAW6".

(b) O and V are dummy variables used for checking transcribing of data and analysis of variance table results.

Table D.3. Data file (a) for pork loin roasts. Mean values of total nitrogen, Low Ionic Strength (LIS) protein solubility extract, non-protein nitrogen (NPN) extract, "sarcoplasmic" protein fraction and "remaining" protein fraction.

A	8	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
6	282		428	79.9	.048654	4.865400	.002831	.002466	.000366	.043357	.126086	12.608600	.007337	.006390	.000947	.112360
6	349		450	85.9	.051780	5.178000	.002793	.002691	.000101	.046296	.128972	12.897200	.006956	.006703	.000253	.115313
6	397		322	79.6	.049241	4.924100	.003263	.002803	.000461	.043175	.139947	13.994700	.009275	.007965	.001309	.122708
6	496		428	92.3	.046740	4.674000	.000937	.002435	-.001497	.043368	.134610	13.461000	.002699	.007012	-.004312	.124899
6	652		300	86.0	.045948	4.594800	.003233	.002859	.000375	.039857	.121716	12.171600	.008379	.007551	.000828	.105787
6	668		375	75.9	.049036	4.903600	.004161	.002124	.002037	.042751	.138654	13.865400	.011765	.006006	.005759	.120883
6	810		375	77.0	.045005	4.500500	.003046	.002659	.000387	.039300	.134337	13.433700	.009093	.007937	.001155	.117307
6	866	R	375	95.0	.051762	5.176200	.003773	.001907	.001866	.046083	.127525	12.752500	.009295	.004698	.004598	.113532
6	919		322	92.2	.045256	4.525600	.003232	.001763	.001470	.040261	.102054	10.205400	.007289	.003975	.003314	.090790
6	544	1	375	86.1	.041880	4.188000	.003282	.001395	.001886	.037203	.115086	11.508600	.009018	.003834	.005184	.102234
6	614	2	375	86.6	.048970	4.897000	.003455	.002314	.001141	.043201	.123218	12.321800	.008693	.005823	.002870	.108701
6	843	3	375	85.9	.048715	4.871500	.002573	.001504	.001069	.044638	.120447	12.044700	.006362	.003719	.002643	.110366
6	033	4	375	85.9	.049619	4.961900	.001281	.003030	-.001749	.045308	.122884	12.288400	.003173	.007504	-.004331	.112206
6	129	5	375	85.0	.045838	4.583800	.002731	.002612	.000120	.040495	.125384	12.538400	.007470	.007144	.000327	.110770

A = Species, pork.
8 = Three-digit code.
C = Central composite rotatable design (CCRD) center points and further informational letters (R = repeat).
D = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Total nitrogen (TN, mg Nitrogen/mg pork), wet weight basis.
G = Percent total nitrogen (% TN), wet weight basis.
H = Low ionic strength (LIS) soluble protein fraction (mg N/mg pork), wet weight basis.
I = Non-protein nitrogen (NPN) extract (mg N/mg pork), wet weight basis.
J = "Sarcoplasmic" protein fraction (LIS-NPN) (mg N/mg pork), wet weight basis.
K = "Remaining" protein fraction (TN -(LIS + NPN)) (mg N/mg pork), wet weight basis.
L = Total nitrogen (TN, mg N/mg pork), dry weight basis.
M = Percent total nitrogen (% TN), dry weight basis.
N = Low ionic strength (LIS) soluble protein fraction (mg N/mg pork), dry weight basis.
O = Non-protein nitrogen (NPN) extract (mg N/mg pork), dry weight basis.
P = "Sarcoplasmic" protein fraction (LIS-NPN) (mg N/mg pork), dry weight basis.
Q = "Remaining" protein fraction (TN - (LIS + NPN)) (mg N/mg pork), dry weight basis.

(a): This is from the computer file called "TCAWD6" - output from the TCA program.

Table D.4. Data file (a) for pork loin roasts. Photovolt filters, calculated Commission Internationale de l'Eclairage (C.I.E.) (English: International Commission on Illumination) values, chromaticity coordinates, Hunter L, aL, and bL values, hue angles, and saturation indices.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
6	282		428	79.9	40.00	31.20	39.30	37.48	39.30	36.85	.330	.346	.324	62.69	-2.99	9.04	.119	9.52
6	349		450	85.9	40.10	33.20	40.30	37.95	40.30	39.21	.323	.343	.334	63.48	-4.38	7.83	4.538	8.97
6	397		322	79.6	37.25	28.90	36.20	34.87	36.20	34.13	.331	.344	.324	60.17	-1.83	8.49	-13.67	8.69
6	496		428	92.3	38.90	29.90	37.90	36.36	37.90	35.31	.332	.346	.322	61.56	-2.30	9.10	-1.061	9.38
6	652		300	86.0	40.90	32.50	40.30	38.44	40.30	38.38	.328	.344	.328	63.48	-3.00	8.60	.282	9.11
6	668		375	75.9	39.30	29.20	37.50	36.54	37.50	34.49	.337	.346	.318	61.24	-.66	9.49	4.058	9.51
6	810		375	77.0	41.25	31.00	43.20	38.42	43.20	36.61	.325	.365	.310	65.73	-10.68	12.99	-2.702	16.82
6	919		322	92.2	39.80	30.10	39.30	37.11	39.30	35.55	.331	.351	.318	62.69	-4.05	10.27	.693	11.04
6	544	1	375	86.1	45.00	35.30	44.20	42.21	44.20	41.69	.329	.345	.325	66.48	-3.03	9.37	.049	9.85
6	614	2	375	86.6	38.30	29.20	36.80	35.75	36.80	34.49	.334	.344	.322	60.66	-.95	8.77	.196	8.82
6	843	3	375	85.9	38.00	30.90	38.20	35.86	38.20	36.49	.324	.346	.330	61.81	-4.61	8.27	4.407	9.47
6	033	4	375	85.9	39.50	30.30	38.20	36.91	38.20	35.78	.333	.344	.323	61.81	-1.56	8.95	.608	9.08
6	129	5	375	85.0	39.50	30.00	37.10	36.85	37.10	35.43	.337	.339	.324	60.91	1.41	8.16	.541	8.28

A = Species, pork.
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points.
D = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Photovolt filter, amber.
G = Photovolt filter, blue.
H = Photovolt filter, green.
I = C.I.E. X-value.
J = C.I.E. Y-value.
K = C.I.E. Z-value.
L = Chromaticity coordinate, x.
M = Chromaticity coordinate, y.
N = Chromaticity coordinate, z.
O = Hunter L-value.
P = Hunter aL-value.
Q = Hunter bL-value.
R = Hue angle (tan bL/aL).
S = Saturation index ((aL**2 + bL**2)**0.5)

(a) This is from the computer file called "COLOR6".

Table D.5. Data file (a) for pork loin roasts. Mean values of sensory evaluation of quality characteristics.

A	B	C	D	E	F	G	H	I	J
6	282		428	79.9	2.60	2.40	3.00	2.90	4.20
6	349		450	85.9	2.20	2.20	3.60	2.00	3.90
6	397		322	79.6	1.90	2.10	2.80	3.00	4.40
6	496		428	92.3	3.10	2.20	2.80	2.90	3.00
6	652		300	86.0	3.80	2.60	2.80	2.90	4.00
6	668		375	75.9	1.40	2.50	2.90	3.60	4.10
6	810		375	77.0	2.80	2.60	2.10	4.10	3.40
6	919		322	92.2	3.60	2.50	3.00	2.80	4.40
6	544	1	375	86.1	3.10	2.80	2.80	3.00	3.50
6	614	2	375	86.6	1.80	2.10	2.80	3.00	4.50
6	843	3	375	85.9	2.60	2.10	3.20	2.60	3.80
6	033	4	375	85.9	3.00	2.90	3.10	2.20	3.80
6	129	5	375	85.0	2.10	2.60	2.10	3.20	3.40

A = Species, pork.
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points.
D = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Tenderness (1 = very tough, 5 = very tender).
G = Flavor (1 = no meaty flavor, 5 = very pronounced meaty flavor).
H = Doneness (1 = very undercooked, 5 = very overcooked).
I = Juiciness (1 = very dry, 5 = very juicy).
J = Color (1 = rosy pink, 5 = greyish brown).

(a) This is from the computer file called "CCRDSE6".

Table D.6. Data file (a) for lamb loin roasts. Initial weights, cooking data, heating rates and cooking times, with cooking temperature-endpoint temperatures (CT-ET) for the central composite rotatable design (CCRO).

A	B	C	D	E	F(b)	G	H	I	J	K	L	M
3	160	R	428	85.6	425.900	.2010	1.3323	30.618	11.669	18.949	.003128	64.25
3	160	X	428*	85.6	424.100	.1922	1.1560	32.775	11.059	21.716	.002726	70.50
3	265		375*	60.3	478.100	.1261	1.4357	12.027	3.012	9.015	.003003	42.00
3	265	R	375	62.0	376.900	.1555	1.3549	12.125	3.847	8.278	.003595	43.25
3	555		300*	75.0	392.500	.1898	.9260	15.949	5.299	10.650	.002359	80.45
3	555	R	300	74.9	366.200	.1933	.9478	16.166	5.625	10.541	.002588	74.70
3	683		450*	75.0	508.900	.1464	1.3496	21.871	8.214	13.657	.002652	55.20
3	683	R	450	75.0	357.700	.1982	1.5933	24.322	7.297	17.025	.004454	44.50
3	691		322*	64.2	438.900	.1435	1.2351	11.643	2.073	9.570	.002814	51.01
3	691	R	322	64.8	440.900	.1393	1.0867	9.912	2.926	6.986	.002465	56.50
3	739		428*	64.8	456.700	.1397	1.5190	20.604	7.160	13.444	.003326	42.00
3	739	R	428	65.0	556.700	.1112	1.2633	15.754	.126	15.628	.002269	49.00
3	767		375*	90.3	446.900	.2021	1.1667	33.855	12.799	21.056	.002611	77.40
3	767	R	375	90.5	339.300	.2546	1.4521	27.350	8.753	18.597	.004280	59.50
3	890		322*	85.6	446.200	.1806	.9799	23.465	8.203	15.262	.002196	82.25
3	890	R	322	85.6	405.800	.2008	.8932	25.456	7.664	17.792	.002201	91.25
3	154	1	375*	75.0	397.300	.1888	1.3112	24.163	7.022	17.141	.003300	57.20
3	154	R1	375	75.0	348.600	.2054	1.3198	23.465	10.499	12.966	.003786	54.25
3	882	2	375*	75.2	486.300	.1546	1.1437	25.272	8.966	16.306	.002352	65.75
3	882	R2	375	75.2	382.800	.1883	1.1695	26.071	9.848	16.223	.003055	61.65
3	926	R3	375	75.5	363.700	.1963	1.1610	22.216	5.582	16.634	.003192	61.50
3	157	4	375*	75.0	447.300	.1632	1.1870	23.832	11.201	12.631	.002654	61.50
3	157	R4	375	78.0	452.400	.1634	1.0948	24.469	10.035	14.434	.002420	67.50
3	888	5	375	75.0	439.700	.1592	1.1058	24.312	7.801	16.511	.002515	63.30
3	888	L5	375*	75.3	425.500	.1690	1.0772	27.873	10.411	17.462	.002532	66.75

A = Species, lamb.
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points and further informational letters (R and X = repeat).
D = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Initial weight (g).
G = Heating rate (deg C/g).
H = Heating rate (deg C/min).
I = Cooking loss (total cooking loss, %).
J = Cooking loss (drip loss, %).
K = Cooking loss (evaporation loss, %).
L = Heating rate (deg C/g/min).
M = Cooking time (min).

(a) The order as given above is identical to the order used in the data file and the regression files called "STRAW3" - output from MOIST program.
Duplicate data sets are available, and "double" regression was performed on them.

(b) F is a dummy variable used for checking transcribing of data and analysis of variance table results.

Table D.7. Data file (a) for lamb loin roasts. Mean values of expressible moisture index (EMI), percent total moisture, proteolytic enzyme values, cooking data, heating rates, cooking times, enzyme weight used.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O(b)	P	Q	R	S	T	U	V(b)
3	160	X	428	85.6	.319	64.561	32.775	11.059	21.716	.1922	1.1560	.002726	70.50	424.100	.019	.024	.005	6.040	5.88	1.125	15.013
3	265		375	60.3	.185	70.090	12.027	3.012	9.015	.1261	1.4357	.003003	42.00	478.100	.256	.277	.021	5.800		2.483	15.006
3	555		300	75.0	.216	68.246	15.949	5.299	10.650	.1898	.9260	.002359	80.45	392.500	.082	.088	.006	5.830	5.88	2.667	15.086
3	683		450	75.0	.227	68.190	21.871	8.214	13.657	.1464	1.3496	.002652	55.20	508.900	.154	.168	.014	5.820		3.033	15.115
3	691		322	64.2	.198	70.232	11.643	2.073	9.570	.1435	1.2351	.002814	51.01	438.900	.180	.194	.014	5.840		1.417	15.162
3	739		428	64.8	.211	70.454	20.604	7.160	13.444	.1397	1.5190	.003326	42.00	456.700	.136	.145	.009	5.710	5.76	2.533	15.070
3	767		375	90.3	.270	63.763	33.855	12.799	21.056	.2021	1.1667	.002611	77.40	446.900	.021	.025	.004	5.900		2.225	15.097
3	890		322	85.6	.223	66.080	23.465	8.203	15.262	.1806	.9799	.002196	82.25	446.200	.029	.036	.007	5.960		2.475	15.039
3	154	1	375	75.0	.244	69.057	24.163	7.022	17.141	.1888	1.3112	.003300	57.20	397.300	.048	.055	.007	5.890		2.450	15.054
3	882	2	375	75.2	.260	66.188	25.272	8.966	16.306	.1546	1.1437	.002352	65.75	486.300	.048	.056	.008	5.830		1.467	14.962
3	926	3	375	75.0	.255	70.492	11.834	2.613	9.221	.1861	1.8642	.004596	40.50	405.600	.214	.229	.015	5.900	5.89	2.767	15.024
3	157	4	375	75.0	.220	67.041	23.832	11.201	12.631	.1632	1.1870	.002654	61.50	447.300	.026	.028	.002	5.930		2.650	15.086
3	888	L5	375	75.3	.287	64.938	24.312	7.801	16.511	.1592	1.1058	.002515	63.30	439.700	.057	.062	.005	5.940	5.85	2.950	15.027

A = Species, lamb.
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points and further informational letters (X = second repeat, L = lamb).
D = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Expressible moisture index (EMI).
G = Percent total moisture (% TM).
H = Cooking loss (total cooking loss, %)
I = Cooking loss (drip loss, %).
J = Cooking loss (evaporation loss, %).
K = Heating rate (deg C/g).
L = Heating rate (deg C/min).
M = Heating rate (deg C/g/min).
N = Cooking time (min).
O = Initial weight (g).
P = Proteolytic enzyme activity (at 0 deg C) (absorbance at 520 nm).
Q = Proteolytic enzyme activity (at 37 deg C) (absorbance at 520 nm).
R = Proteolytic enzyme activity difference (37 deg C - 0 deg C) (absorbance at 520 nm).
S = pH of lamb and redistilled water slurry.
T = pH of extract, after enzyme removal.
U = Warner-Bratzler shear values (kg/127 mm diameter core).
V = Enzyme weight (g).

(a) This is from the computer file called "PHENZ3" but the cooking loss data, heating rates, initial weight and cooking time were previously obtained from "STRAW3".

(b) O and V are dummy variables used for checking transcribing of data and analysis of variance table results.

Table D.8. Data file (a) for lamb loin roasts. Mean values of total nitrogen, Low Ionic Strength (LIS) protein solubility extract, non-protein nitrogen (NPN) extract, "sarcoplasmic" protein fraction and "remaining" protein fraction.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
3	160	X	428	85.6	.044319	4.431900	.003353	.002273	.001080	.038693	.125057	12.505700	.009461	.006414	.003047	.109182
3	265		375	60.3	.037832	3.783200	.002617		.002617	.035215	.126490	12.649000	.008751		.008751	.117739
3	555		300	75.0	.039869	3.986900	.003107	.003624	-.000517	.033138	.125555	12.555500	.009786	.011413	-.001627	.104356
3	683		450	75.0	.040364	4.036400	.003269	.003319	-.000050	.033776	.126892	12.689200	.010277	.010435	-.000158	.106179
3	691		322	64.2	.038687	3.868700	.000500	.002483	-.001983	.035704	.129961	12.996100	.001679	.008340	-.006661	.119942
3	739		428	64.8	.040562	4.056200	.004029	.002482	.001547	.034051	.137285	13.728500	.013637	.008401	.005235	.115247
3	767		375	90.3	.057189	5.718900	.002892	.003236	-.000344	.051061	.157818	15.781800	.007980	.008930	-.000950	.140909
3	890		322	85.6	.044116	4.411600	.003915	.002733	.001182	.037467	.130060	13.006000	.011543	.008059	.003484	.110459
3	154	1	375	75.0	.042538	4.253800	.003257	.003616	-.000360	.035665	.137473	13.747300	.010525	.011687	-.001163	.115262
3	882	2	375	75.2	.046388	4.638800	.004509	.003672	.000836	.038207	.137194	13.719400	.013334	.010861	.002474	.112999
3	926	3	375	75.0	.039795	3.979500	.004387	.002745	.001642	.032662	.134858	13.485800	.014868	.009303	.005565	.110687
3	157	4	375	75.0	.043459	4.345900	.003359	.002597	.000762	.037504	.131858	13.185800	.010190	.007879	.002311	.113789
3	888	L5	375	75.3	.040037	4.003700	.002454	.002538	-.000084	.035046	.114188	11.418800	.006998	.007237	-.000239	.099953

A = Species, lamb.
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points and further informational letters (X = repeat, L = lamb).
D = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Total nitrogen (TN, mg Nitrogen/mg lamb), wet weight basis.
G = Percent total nitrogen (% TN), wet weight basis.
H = Low ionic strength (LIS) soluble protein fraction (mg N/mg lamb), wet weight basis.
I = Non-protein nitrogen (NPN) extract (mg N/mg lamb), wet weight basis.
J = "Sarcoplasmic" protein fraction (LIS-NPN) (mg N/mg lamb), wet weight basis.
K = "Remaining" protein fraction (TN -(LIS + NPN)) (mg N/mg lamb), wet weight basis.
L = Total nitrogen (TN, mg N/mg lamb), dry weight basis.
M = Percent total nitrogen (% TN), dry weight basis.
N = Low ionic strength (LIS) soluble protein fraction (mg N/mg lamb), dry weight basis.
O = Non-protein nitrogen (NPN) extract (mg N/mg lamb), dry weight basis.
P = "Sarcoplasmic" protein fraction (LIS-NPN) (mg N/mg lamb), dry weight basis.
Q = "Remaining" protein fraction (TN - (LIS + NPN)) (mg N/mg lamb), dry weight basis.

(a): This is from the computer file called "TCAW03" - output from the TCA program.

Table D.9. Data file (a) for lamb loin roasts. Photovolt filters, calculated Commission Internationale de l'Eclairage (C.I.E.) (English: International Commission on Illumination) values, chromaticity coordinates, Hunter L, aL, and bL values, hue angles, and saturation indices.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
3	160	X	428	85.6	21.50	15.00	20.10	19.80	20.10	17.72	.344	.349	.307	44.83	.36	7.96	.121	7.97
3	265		375	60.3	26.70	15.60	21.90	23.99	21.90	18.42	.373	.341	.286	46.80	9.60	9.42	1.495	13.45
3	555		300	75.0	21.50	13.50	18.90	19.50	18.90	15.94	.359	.348	.293	43.47	3.99	8.69	-1.440	9.57
3	683		450	75.0	22.20	15.00	20.00	20.35	20.00	17.72	.350	.344	.305	44.72	2.94	7.83	-.518	8.36
3	691		322	64.2	23.80	12.80	18.30	21.16	18.30	15.12	.388	.335	.277	42.78	13.45	9.00	.791	16.18
3	739		428	64.8	23.40	13.80	19.20	21.05	19.20	16.30	.372	.340	.288	43.82	9.06	8.63	1.406	12.51
3	767		375	90.3	23.50	16.40	20.60	21.64	20.60	19.37	.351	.334	.314	45.39	5.68	6.48	2.181	8.61
3	890		322	85.6	23.40	16.20	21.90	21.52	21.90	19.13	.344	.350	.306	46.80	.19	8.53	1.293	8.53
3	154	1	375	75.0	22.20	15.10	20.80	20.36	20.80	17.83	.345	.353	.302	45.61	-.11	8.75	-1.577	8.75
3	882	2	375	75.2	25.00	17.90	23.60	23.11	23.60	21.14	.341	.348	.312	48.58	-.10	8.21	-.445	8.21
3	926	3	375	75.0	22.60	14.80	19.90	20.62	19.90	17.48	.356	.343	.301	44.61	4.44	8.00	-4.252	9.15
3	157	4	375	75.0	22.10	15.30	20.70	20.33	20.70	18.07	.344	.350	.306	45.50	.13	8.31	1.923	8.31
3	888	L5	375	75.3	23.90	17.10	22.60	22.09	22.60	20.20	.340	.348	.311	47.54	-.25	8.10	-1.504	8.10

A = Species, lamb.
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points and further informational letters (X = second repeat, L = lamb).
D = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Photovolt filter, amber.
G = Photovolt filter, blue.
H = Photovolt filter, green.
I = C.I.E. X-value.
J = C.I.E. Y-value.
K = C.I.E. Z-value.
L = Chromaticity coordinate, x.
M = Chromaticity coordinate, y.
N = Chromaticity coordinate, z.
O = Hunter L-value.
P = Hunter aL-value.
Q = Hunter bL-value.
R = Hue angle (tan bL/aL).
S = Saturation index ((aL**2 + bL**2)**0.5)

(a) This is from the computer file called "COLOR3".

Table D.10. Data file (a) for lamb loin roasts. Mean values of sensory evaluation of quality characteristics.

A	B	C	D	E	F	G	H	I	J
3	160	X	428	85.6	4.00	2.80	3.00	2.70	4.20
3	265		375	60.3	4.00	1.90	2.00	4.70	2.00
3	555		300	75.0	4.70	2.50	2.70	3.70	2.00
3	683		450	75.0	3.50	3.00	3.00	3.20	3.00
3	691		322	64.4	4.20	2.10	2.30	4.70	1.60
3	739		428	64.8	5.00	2.00	1.90	5.00	1.90
3	767		375	90.3	4.10	3.10	3.10	3.40	3.00
3	890		322	85.6	3.20	3.20	3.00	3.20	3.30
3	154	1	375	75.0	3.40	2.70	3.10	4.00	3.40
3	882	2	375	75.2	4.40	2.30	2.90	3.70	4.30
3	926	3	375	75.0	2.50	2.50	2.70	3.50	2.50
3	157	4	375	75.0	4.80	2.30	2.70	3.70	3.70
3	888	L5	375	75.3	3.60	2.40	3.00	3.90	4.60

A = Species, lamb.
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points and further informational letters (X = second repeat, L = lamb).
D = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Tenderness (1 = very tough, 5 = very tender).
G = Flavor (1 = no meaty flavor, 5 = very pronounced meaty flavor).
H = Doneness (1 = very undercooked, 5 = very overcooked).
I = Juiciness (1 = very dry, 5 = very juicy).
J = Color (1 = rosy red, 5 = brownish grey).

(a) This is from the computer file called "CCRDSE3".

Table D.11. Data file (a) for roast turkey breasts. Initial weights, cooking data, heating rates and cooking times, with cooking temperature-endpoint temperatures (CT-ET) for the central composite rotatable design (CCRD).

A	B	C	D	E	F(b)	G	H	I	J	K	L	M
4	248		375*	94.9	4437.900	.0205	.4603	37.739	5.430	32.309	.000104	197.25
4	248	R	375	95.0	4096.100	.0187	.4526	36.046	7.014	29.032	.000110	169.25
4	327		322*	78.0	3646.100	.0203	.4105	27.062	1.451	25.611	.000113	180.25
4	327	R	322	78.0	3742.500	.0200	.5769	15.853	2.159	13.694	.000154	130.00
4	538		428*	77.9	4005.900	.0186	.8076	27.944	8.041	19.903	.000202	92.50
4	538	R	428	78.0	4216.100	.0185	.8739	25.939	5.242	20.697	.000207	89.25
4	605		322	92.0	4128.000	.0214	.4667	26.245	6.177	20.068	.000113	189.00
4	605	R	322*	92.0	4236.400	.0208	.4103	29.369	5.347	24.022	.000097	214.50
4	715		300	85.0	3913.600	.0204	.4015	27.422	9.447	17.975	.000103	199.25
4	715	R	300*	84.9	3837.700	.0213	.3616	28.851	8.153	20.698	.000094	226.50
4	808		428*	92.0	3809.400	.0228	.5597	36.121	5.090	31.031	.000147	155.25
4	808	R	428	92.0	3583.900	.0246	.6447	36.000	4.646	31.354	.000180	136.50
4	841		375*	75.0	4097.600	.0183	.6494	20.195	4.827	15.368	.000158	115.50
4	841	R	375	75.1	3936.400	.0182	.6051	25.163	5.668	19.495	.000154	118.50
4	997		450*	85.0	4045.800	.0198	.9357	23.993	5.584	18.409	.000231	85.50
4	997	R	450	85.0	3952.300	.0205	.6585	29.707	4.600	25.107	.000167	123.00
4	881	1	375*	85.1	4474.200	.0183	.5103	30.774	12.279	18.495	.000114	160.50
4	881	R1	375	85.0	4385.000	.0194	.6641	27.117	8.449	18.668	.000151	128.00
4	761	2	375*	84.5	3874.200	.0208	.5552	33.088	6.972	26.116	.000143	145.00
4	761	R2	375	85.0	3964.200	.0214	.6093	31.177	6.614	24.563	.000154	139.50
4	056	3	375*	85.0	4330.300	.0192	.4897	33.561	7.494	33.988	.000113	169.50
4	056	R3	375	85.0	4426.000	.0185	.5325	31.085	7.492	23.593	.000120	154.00
4	733	4	375*	85.3	3588.100	.0228	.5508	31.724	5.178	26.546	.000154	148.50
4	733	R4	375	85.1	3944.400	.0206	.6620	26.998	5.195	21.803	.000168	122.50
4	697	5	375*	85.0	4136.800	.0193	.5889	26.552	8.233	18.319	.000142	135.50
4	697	R5	375	85.0	3760.200	.0204	.6091	25.935	4.114	21.821	.000162	125.75

A = Species, turkey breast.
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points and further informational letters (R = repeat).
D = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Initial weight (g).
G = Heating rate (deg C/g).
H = Heating rate (deg C/min).
I = Cooking loss (total cooking loss, %).
J = Cooking loss (drip loss, %).
K = Cooking loss (evaporation loss, %).
L = Heating rate (deg C/g/min).
M = Cooking time (min).

(a) The order as given above is identical to the order used in the data file and the regression files called "STRAW4" - output from MOIST program.
Duplicate data sets are available, and "double" regression was performed on them.

(b) F is a dummy variable used for checking transcribing of data and analysis of variance table results.

No cooking data is available for roast turkey thighs, as turkey halves were cooked and the endpoint temperatures of the breasts were monitored for the CCRD.

Table D.12. Data file (a) for roast turkey breasts. Mean values of expressible moisture index (EMI), percent total moisture, proteolytic enzyme values, cooking data, heating rates, cooking times, enzyme weight used.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O(b)	P	Q	R	S	T	U	V(b)
4	248		375	95.0	.288	67.499	37.739	5.430	32.309	.0205	.4603	.000104	197.25	4437.900	.005	.016	.011	6.240	6.05	3.525	15.028
4	327		322	78.0	.223	69.772	27.062	1.451	25.611	.0203	.4105	.000113	180.25.	3646.100	.007	.018	.011	6.320	6.02	2.000	15.065
4	538		428	77.9	.240	62.284	27.944	8.041	19.903	.0186	.8076	.000202	92.50	4005.900	.012	.015	.003	6.280	6.04	2.075	15.076
4	605	R	322	92.0	.303	67.700	29.369	5.347	24.022	.0208	.4103	.000097	214.50	4236.400	.005	.008	.003	6.290	6.11	1.700	15.066
4	715	R	300	85.0	.275	67.624	28.851	8.153	20.698	.0213	.3616	.000094	226.50	3837.700	.005	.012	.007	6.270	6.04	1.750	15.030
4	808		428	92.0	.297	67.103	36.121	5.090	31.031	.0228	.5597	.000147	155.25	3809.400	.003	.009	.006	6.230	6.01	1.850	15.070
4	841		375	75.1	.228	69.824	20.195	4.827	15.368	.0183	.6494	.000158	115.50	4097.600	.008	.013	.005	6.370	6.15	1.530	15.058
4	997		450	85.0	.258	68.173	23.993	5.584	18.409	.0198	.9357	.000231	85.50	4045.800	.007	.020	.013	6.140	6.03	.983	15.001
4	881	1	375	85.1	.188	66.186	30.774	12.279	18.495	.0183	.5103	.000114	160.50	4474.200	.005	.008	.003	6.070	5.93	1.383	15.720
4	761	2	375	84.5	.216	66.430	33.088	6.972	26.116	.0208	.5552	.000143	145.00	3874.200	.008	.014	.006	6.240	5.98	3.000	15.004
4	056	3	375	85.0	.305	66.679	33.561	7.494	26.067	.0192	.4897	.000113	169.50	4330.300	.011	.025	.014	6.290	6.08	1.875	15.078
4	733	4	375	85.1	.274	67.710	31.724	5.178	26.546	.0228	.5508	.000154	148.50	3588.100	.009	.018	.009	6.330	6.09	1.717	15.067
4	697	5	375	85.0	.288	68.460	26.552	8.233	18.319	.0193	.5889	.000142	135.50	4136.800	.005	.015	.010	6.210	6.00	1.333	15.083

A = Species, turkey breast.
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points and further informational letters (R = repeat).
D = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Expressible moisture index (EMI).
G = Percent total moisture (% TM).
H = Cooking loss (total cooking loss, %)
I = Cooking loss (drip loss, %).
J = Cooking loss (evaporation loss, %).
K = Heating rate (deg C/g).
L = Heating rate (deg C/min).
M = Heating rate (deg C/g/min).
N = Cooking time (min).
O = Initial weight (g).
P = Proteolytic enzyme activity (at 0 deg C) (absorbance at 520 nm).
Q = Proteolytic enzyme activity (at 37 deg C) (absorbance at 520 nm).
R = Proteolytic enzyme activity difference (37 deg C - 0 deg C) (absorbance at 520 nm).
S = pH of turkey breast and redistilled water slurry.
T = pH of extract, after enzyme removal.
U = Warner-Bratzler shear values (kg/127 mm diameter core).
V = Enzyme weight (g).

(a) This is from the computer file called "PHENZ4" but the cooking loss data, heating rates, initial weight and cooking time were previously obtained from "STRAW4".

(b) O and V are dummy variables used for checking transcribing of data and analysis of variance table results.

Table D.13. Data file (a) for roast turkey breasts. Mean values of total nitrogen, Low Ionic Strength (LIS) protein solubility extract non-protein nitrogen (NPN) extract, "sarcoplasmic" protein fraction and "remaining" protein fraction.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
4	248		375	95.0	.049462	4.946200	.004237	.003649	.000588	.041576	.152184	15.218400	.013036	.011227	.001809	.127921
4	327		322	78.0	.047409	4.740900	.004666	.004585	.000081	.038158	.156837	15.683700	.015436	.015167	.000269	.126233
4	538		428	77.9	.052981	5.298100	.005975	.005017	.000958	.041989	.140472	14.047200	.015843	.013302	.002541	.111327
4	605	R	322	92.0	.049947	4.994700	.004518	.004308	.000211	.041121	.154638	15.463800	.013989	.013336	.000653	.127312
4	715	R	300	85.0	.049202	4.920200	.005937	.004421	.001516	.038843	.151968	15.196800	.018338	.013656	.004682	.119973
4	808		428	92.0	.052825	5.282500	.004918	.004851	.000067	.043055	.160576	16.057600	.014951	.014747	.000203	.130879
4	841		375	75.1	.039259	3.925900	.003735	.004149	-.000414	.031374	.130096	13.009600	.012378	.013750	-.001372	.103969
4	997		450	85.0	.047486	4.748600	.005489	.005304	.000184	.036693	.149199	14.919900	.017245	.016666	.000578	.115288
4	881	1	375	85.1	.049513	4.951300	.004727	.004287	.000440	.040499	.146427	14.642700	.013980	.012678	.001302	.119768
4	761	2	375	84.5	.053135	5.313500	.004435	.004351	.000083	.044349	.158280	15.828000	.013210	.012962	.000248	.132108
4	056	3	375	85.0	.053093	5.309300	.004350	.004208	.000142	.044535	.159336	15.933600	.013055	.012628	.000427	.133652
4	733	4	375	85.1	.050988	5.098800	.004736	.004662	.000073	.041590	.157906	15.790600	.014667	.014439	.000227	.128801
4	697	5	375	85.0	.050555	5.055500	.004952	.004578	.000375	.041025	.160286	16.028600	.015701	.014514	.001188	.130071

A = Species, turkey breast.
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points and further informational letters (R = repeat).
D = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Total nitrogen (TN, mg Nitrogen/mg turkey breast), wet weight basis.
G = Percent total nitrogen (% TN), wet weight basis.
H = Low ionic strength (LIS) soluble protein fraction (mg N/mg turkey breast), wet weight basis.
I = Non-protein nitrogen (NPN) extract (mg N/mg turkey breast), wet weight basis.
J = "Sarcoplasmic" protein fraction (LIS-NPN) (mg N/mg turkey breast), wet weight basis.
K = "Remaining" protein fraction (TN -(LIS + NPN)) (mg N/mg turkey breast), wet weight basis.
L = Total nitrogen (TN, mg N/mg turkey breast), dry weight basis.
M = Percent total nitrogen (% TN), dry weight basis.
N = Low ionic strength (LIS) soluble protein fraction (mg N/mg turkey breast), dry weight basis.
O = Non-protein nitrogen (NPN) extract (mg N/mg turkey breast), dry weight basis.
P = "Sarcoplasmic" protein fraction (LIS-NPN) (mg N/mg turkey breast), dry weight basis.
Q = "Remaining" protein fraction (TN - (LIS + NPN)) (mg N/mg turkey breast), dry weight basis.

(a): This is from the computer file called "TCAWD4" - output from the TCA program.

Table D.14. Data file (a) for roast turkey breasts. Mean values of sensory evaluation of quality characteristics.

A	B	C	D	E	F	G	H	I
4	248		375	95.0	3.50	2.60	3.30	2.50
4	327		322	78.0	4.00	2.50	2.70	3.70
4	538		428	77.9	2.60	2.00	3.20	2.20
4	605	R	322	92.0	4.80	2.80	3.30	2.40
4	715	R	300	85.0	4.20	2.10	3.60	1.80
4	808		428	92.0	3.30	1.80	3.80	1.50
4	841		375	75.1	3.50	2.20	3.20	2.70
4	997		450	85.0	3.90	2.30	3.60	2.20
4	881	1	375	85.1	3.20	2.20	3.40	2.60
4	761	2	375	84.5	3.70	2.60	3.70	2.00
4	056	3	375	85.0	3.90	2.00	4.00	1.60
4	733	4	375	85.1	4.30	2.50	3.10	2.90
4	697	5	375	85.0	3.80	2.40	3.30	2.40

A = Species, turkey breast.
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points and further informational letters (R = repeat).
D = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Tenderness (1 = very tough, 5 = very tender).
G = Flavor (1 = no meaty flavor, 5 = very pronounced meaty flavor).
H = Doneness (1 = very undercooked, 5 = very overcooked).
I = Juiciness (1 = very dry, 5 = very juicy).

(a) This is from the computer file called "CCRDSE4".

Table D.15. Data file (a) for roast turkey thighs. Mean values of expressible moisture index (EMI), percent total moisture, proteolytic enzyme values, cooking times, enzyme weight used.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O(b)	P	Q	R	S	T	U	V(b)
5	248		375	197.25	.445	60.899									.060	.059	-.001	6.480	6.32	1.700	15.065
5	327		322	130.00	.388	67.376									.060	.069	.009	6.710	6.58	.750	15.012
5	538		428	92.50	.286	66.645									.052	.061	.009	6.720	6.56	2.850	15.079
5	605	R	322	214.50	.418	66.879									.161	.176	.015	6.910	6.66	2.500	15.009
5	715	R	300	226.50	.394	65.872									.094	.106	.012	6.640	6.47	1.767	15.027
5	808		428	155.25	.436	64.053									.094	.110	.016	6.710	6.42	1.362	15.022
5	841		375	115.50	.354	67.388									.045	.054	.009	6.690	6.45	2.233	14.992
5	997		450	85.50	.259	67.083									.051	.055	.004	6.580	6.39	2.275	15.064
5	881	1	375	160.50	.358	59.860									.002	.031	.029	6.390	6.22	2.450	15.010
5	761	2	375	145.00	.357	62.618									.023	.027	.004	6.410	6.20	2.317	15.064
5	056	3	375	169.50	.480	64.462									.068	.079	.011	6.650	6.44	2.133	15.024
5	733	4	375	148.50	.517	65.814									.101	.116	.015	6.780	6.50	1.075	15.060
5	697	5	375	135.50	.305	66.238									.045	.055	.010	6.760	6.50	1.525	14.981

A = Species, turkey thigh.
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points and further informational letters (R = repeat).
D = Cooking temperature (deg F).
E = Cooking time (min).
F = Expressible moisture index (EMI).
G = Percent total moisture (% TM).
H = Cooking loss (total cooking loss, %)
I = Cooking loss (drip loss, %).
J = Cooking loss (evaporation loss, %).
K = Heating rate (deg C/g).
L = Heating rate (deg C/min).
M = Heating rate (deg C/g/min).
N = Cooking time (min).
O = Initial weight (g).
P = Proteolytic enzyme activity (at 0 deg C) (absorbance at 520 nm).
Q = Proteolytic enzyme activity (at 37 deg C) (absorbance at 520 nm).
R = Proteolytic enzyme activity difference (37 deg C - 0 deg C) (absorbance at 520 nm).
S = pH of turkey thigh and redistilled water slurry.
T = pH of extract, after enzyme removal.
U = Warner-Bratzler shear values (kg/127 mm diameter core).
V = Enzyme weight (g).

(a) This is from the computer file called "PHENZ5" but the cooking time was previously obtained from "STRAW4". H through O are omitted (see STRAW4).

(b) O and V are dummy variables used for checking transcribing of data and analysis of variance table results.

Table D.16. Data file (a) for roast turkey thighs. Mean values of total nitrogen, Low Ionic Strength (LIS) protein, solubility extract non-protein nitrogen (NPN) extract, "sarcoplasmic" protein fraction and "remaining" protein fraction.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
5	248		375	197.25	.051640	5.164000	.004574	.000608	.003967	.046458	.132068	13.206800	.011698	.001554	.010144	.118815
5	327		322	130.00	.049255	4.925500	.002441	.002097	.000343	.044717	.150975	15.097500	.007481	.006429	.001052	.137065
5	538		428	92.50	.039713	3.971300		.002041	-.002041	.037673	.119062	11.906200		.006118	-.006118	.112944
5	605	R	322	214.50	.049984	4.998400	.003733	.003331	.000402	.042920	.150913	15.091300	.011270	.010057	.001213	.129587
5	715	R	300	226.50	.048723	4.872300	.003992	.002581	.001411	.042149	.142763	14.276300	.011698	.007563	.004135	.123501
5	808		428	155.25	.043847	4.384700	.004043	.002770	.001273	.037033	.121976	12.197600	.011248	.007706	.003542	.103022
5	841		375	115.50	.047949	4.794900	.002863	.002679	.000184	.042407	.147026	14.702600	.008779	.008213	.000565	.130034
5	997		450	85.50	.047322	4.732200	.003398	.002394	.001004	.041531	.143763	14.376300	.010323	.007272	.003051	.126168
5	881	1	375	160.50	.035320	3.532000	.002464	.002520	-.000057	.030336	.087992	8.799200	.006138	.006279	-.000141	.075576
5	761	2	375	145.00	.047923	4.792300	.003074	.002452	.000621	.042397	.128198	12.819800	.008223	.006560	.001663	.113415
5	056	3	375	169.50	.049558	4.955800	.003499	.003565	-.000066	.042493	.139452	13.945200	.009846	.010033	-.000187	.119573
5	733	4	375	148.50	.046200	4.620000	.003939	.003714	.000225	.038547	.135144	13.514400	.011522	.010863	.000659	.112758
5	697	5	375	135.50	.048681	4.868100	.003657	.002932	.000725	.042092	.144191	14.419100	.010833	.008685	.002148	.124673

A = Species, turkey thigh.
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points and further informational letters (R = repeat).
D = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Total nitrogen (TN, mg Nitrogen/mg turkey thigh), wet weight basis.
G = Percent total nitrogen (% TN), wet weight basis.
H = Low ionic strength (LIS) soluble protein fraction (mg N/mg turkey thigh), wet weight basis.
I = Non-protein nitrogen (NPN) extract (mg N/mg turkey thigh), wet weight basis.
J = "Sarcoplasmic" protein fraction (LIS-NPN) (mg N/mg turkey thigh), wet weight basis.
K = "Remaining" protein fraction (TN -(LIS + NPN)) (mg N/mg turkey thigh), wet weight basis.
L = Total nitrogen (TN, mg N/mg turkey thigh), dry weight basis.
M = Percent total nitrogen (% TN), dry weight basis.
N = Low ionic strength (LIS) soluble protein fraction (mg N/mg turkey thigh), dry weight basis.
O = Non-protein nitrogen (NPN) extract (mg N/mg turkey thigh), dry weight basis.
P = "Sarcoplasmic" protein fraction (LIS-NPN) (mg N/mg turkey thigh), dry weight basis.
Q = "Remaining" protein fraction (TN - (LIS + NPN)) (mg N/mg turkey thigh), dry weight basis.

(a): This is from the computer file called "TCAWD5" - output from the TCA program.

Table D.17. Data file (a) for roast turkey thighs. Mean values of sensory evaluation of quality characteristics.

A	B	C	D	E	F	G	H	I
5	248		375	197.25	3.30	3.30	3.90	2.10
5	327	R	322	130.00	2.70	2.90	2.80	3.20
5	538		428	92.50	2.80	2.40	3.10	2.70
5	605	R	322	214.50	4.00	2.90	3.30	2.90
5	715	R	300	226.50	3.60	2.80	3.40	3.00
5	808		428	155.25	2.80	2.50	3.70	2.00
5	841		375	115.50	3.40	2.70	3.20	2.70
5	997		450	85.50	3.30	2.60	3.40	2.40
5	881	1	375	160.50	3.20	2.80	3.50	2.50
5	761	2	375	145.00	3.30	2.70	4.00	2.30
5	056	3	375	169.50	3.60	2.60	3.10	2.60
5	733	4	375	148.50	3.20	2.80	3.20	2.40
5	697	5	375	135.50	2.50	2.50	3.50	2.80

A = Species, turkey thigh.
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points and further informational letters (R = repeat).
D = Cooking temperature (deg F).
E = Cooking time (min).
F = Tenderness (1 = very tough, 5 = very tender).
G = Flavor (1 = no meaty flavor, 5 = very pronounced meaty flavor).
H = Doneness (1 = very undercooked, 5 = very overcooked).
I = Juiciness (1 = very dry, 5 = very juicy).

(a) This is from the computer file called "CCRDSE5".

Table D.18. Data file (a) for control beef. Initial weights, cooking data, heating rates and cooking times, with cooking temperature-endpoint temperatures (CT-ET) for the central composite rotatable design (CCRD).

A	B	C	D	E	F(b)	G	H	I	J	K	L	M
1	061		428	85.5	88.309	.9104	1.9030	39.318	2.152	37.166	.021549	42.25
1	275		450	74.8	89.075	.7612	5.2154	15.487	3.256	12.231	.058550	13.00
1	441		300	74.9	91.278	.7439	1.0996	32.690	4.492	28.198	.012047	61.75
1	491		322	64.4	83.441	.6903	1.9692	22.007	3.955	18.052	.023600	29.25
1	561		322	85.5	84.916	.9492	.8906	46.709	.707	46.002	.010488	90.50
1	562	X	375	60.0	86.945	.6119	2.7240	16.371	1.725	14.646	.031330	19.53
1	757		375	89.8	90.743	.9334	1.3772	42.169	2.314	39.855	.015177	61.50
1	917		428	64.8	90.620	.6378	2.8900	22.034	4.193	17.841	.031891	20.00
1	351	R1	375	75.0	84.591	.7920	2.0000	28.294	.709	27.585	.023643	33.50
1	288	2	375	75.0	86.020	.7928	2.2545	31.945	2.674	29.271	.026210	30.25
1	628	3	375	74.9	88.142	.7601	2.0000	31.175	1.929	29.246	.022691	33.50
1	251	4	375	75.0	93.808	.7462	2.0000	29.570	3.091	26.479	.021320	35.00
1	444	5	375	75.0	89.112	.7620	2.0119	32.557	3.815	28.742	.022577	33.75

A = Species, beef (control).
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points and further informational letters (R and X = repeat).
D = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Initial weight (g).
G = Heating rate (deg C/g).
H = Heating rate (deg C/min).
I = Cooking loss (total cooking loss, %).
J = Cooking loss (drip loss, %).
K = Cooking loss (evaporation loss, %).
L = Heating rate (deg C/g/min).
M = Cooking time (min).

(a) The order as given above is identical to the order used in the data file and the regression files called "STRAW1" - output from MOIST program.
No duplicate data sets are available for "double" regressions.

(b) F is a dummy variable used for checking transcribing of data and analysis of variance table results.

Table D.19. Data file (a) for control beef. Mean values of expressible moisture index (EMI), percent total moisture, proteolytic enzyme values, cooking data, heating rates, cooking times, enzyme weight used.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O(b)	P	Q	R	S	T	U	V(b)
1	061		428	85.5	.343	55.751	39.318	2.152	37.166	.9104	1.9030	.021549	42.25	88.309	.014	.021	.007	5.623			15.000
1	275		450	74.8	.313	67.297	15.487	3.256	12.231	.7612	5.2154	.058550	13.00	89.075	.406	.442	.036	5.060			14.974
1	441		300	74.9	.333	57.668	32.690	4.492	28.198	.7439	1.0996	.012047	61.75	91.278	.060	.054	-.006	6.180			15.072
1	491		322	64.4	.296	67.012	22.007	3.955	18.052	.6903	1.9692	.023600	29.25	83.441	.404	.430	.026	5.560			14.941
1	561		322	85.5	.465	54.095	46.709	.707	46.002	.9492	.8906	.010488	90.50	84.916	.007	.010	.003	5.621			15.985
1	562	X	375	60.0	.266	62.200	16.371	1.725	14.646	.6119	2.7240	.031330	19.53	86.945	.422	.457	.035	5.516			15.059
1	757		375	89.8	.394	55.517	42.169	2.314	39.855	.9334	1.3772	.015177	61.50	90.743	.016	.017	.001	5.609			14.955
1	917		428	64.8	.250	64.342	22.034	4.193	17.841	.6378	2.8900	.031891	20.00	90.620	.237	.265	.028	5.400			15.075
1	351	R1	375	75.0	.210	59.636	28.294	.709	27.585	.7920	2.0239	.023643	33.50	84.591	.161	.169	.008	5.675			15.000
1	288	2	375	75.0	.312	58.658	31.945	2.674	29.271	.7928	2.2545	.026210	30.25	86.020	.103	.099	-.004	5.542			15.086
1	628	3	375	74.9	.257	61.847	31.175	1.929	29.246	.7601	2.0000	.022691	33.50	88.142	.093	.101	.008	5.300			15.035
1	251	4	375	75.0	.302	59.518	29.570	3.091	26.479	.7462	2.0000	.021320	35.00	93.808	.059	.064	.005	5.580			15.010
1	444	5	375	75.0	.286	58.861	32.557	3.815	28.742	.7620	2.0119	.022577	33.75	89.112	.058	.068	.010	5.692			14.972

A = Species, beef (control).
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points and further informational letters (R and X = repeat).
D = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Expressible moisture index (EMI).
G = Percent total moisture (% TM).
H = Cooking loss (total cooking loss, %)
I = Cooking loss (drip loss, %).
J = Cooking loss (evaporation loss, %).
K = Heating rate (deg C/g).
L = Heating rate (deg C/min).
M = Heating rate (deg C/g/min).
N = Cooking time (min).
O = Initial weight (g).
P = Proteolytic enzyme activity (at 0 deg C) (absorbance at 520 nm).
Q = Proteolytic enzyme activity (at 37 deg C) (absorbance at 520 nm).
R = Proteolytic enzyme activity difference (37 deg C - 0 deg C) (absorbance at 520 nm).
S = pH of beef (control) and redistilled water slurry.
T = pH of extract, after enzyme removal.
U = Warner-Bratzler shear values (kg/127 mm diameter core).
V = Enzyme weight (g).

(a) This is from the computer file called "PHENZ1" but the cooking loss data, heating rates, initial weight and cooking time were previously obtained from "STRAW1".

(b) O and V are dummy variables used for checking transcribing of data and analysis of variance table results.

Table D.20. Data file (a) for control beef. Mean values of total nitrogen, Low Ionic Strength (LIS) protein solubility extract, non-protein nitrogen (NPN) extract, "sarcoplasmic" protein fraction and "remaining" protein fraction.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1	061		428	85.5	.039173	3.917300	.002892	.001389	.001502	.034892	.088528	8.852800	.006535	.003140	.003395	.078853
1	275		450	74.8	.042619	4.261900	.004453	.003404	.001050	.034762	.130322	13.032200	.013618	.010407	.003211	.106296
1	441		300	74.9			.005516	.000329	.005187	-.005845			.013031	.000778	.012253	-.013809
1	491		322	64.4	.044895	4.489500	.002875	.002803	.000072	.039216	.136096	13.609600	.008716	.008498	.000218	.118882
1	561		322	85.5	.054576	5.457600	.002928	.002043	.000885	.049605	.118890	11.889000	.006379	.004451	.001928	.108060
1	562	X	375	60.0	.042246	4.224600	.005869	.003579	.002290	.032798	.111762	11.176200	.015526	.009469	.006058	.086767
1	757		375	89.8	.048116	4.811600	.005016	.003367	.001648	.039734	.108168	10.816800	.011275	.007570	.003706	.089323
1	917		428	64.8	.044458	4.445800	.003906	.002688	.001218	.037864	.124680	12.468000	.010954	.007537	.003417	.106188
1	351	R1	375	75.0	.044939	4.493900	.002929	.002784	.000145	.039226	.111334	11.133400	.007257	.006897	.000360	.097181
1	288	2	375	75.0	.034895	3.489500	.003038	.002728	.000310	.029129	.084406	8.440600	.007349	.006599	.000751	.070459
1	628	3	375	74.9	.044047	4.404700	.003699	.002581	.001118	.037767	.115448	11.544800	.009694	.006764	.002931	.098990
1	251	4	375	75.0	.046137	4.613700	.002281	.002199	.000082	.041657	.113969	11.396900	.005635	.005433	.000202	.102902
1	444	5	375	75.0	.045028	4.502800	.003283	.002195	.001088	.039550	.109453	10.945300	.007980	.005335	.002645	.096137

A = Species, beef (control).
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points and further informational letters (R and X = repeat).
D = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Total nitrogen (TN, mg Nitrogen/mg beef (control)), wet weight basis.
G = Percent total nitrogen (% TN), wet weight basis.
H = Low ionic strength (LIS) soluble protein fraction (mg N/mg beef (control)), wet weight basis.
I = Non-protein nitrogen (NPN) extract (mg N/mg beef (control)), wet weight basis.
J = "Sarcoplasmic" protein fraction (LIS-NPN) (mg N/mg beef (control)), wet weight basis.
K = "Remaining" protein fraction (TN -(LIS + NPN)) (mg N/mg beef (control)), wet weight basis.
L = Total nitrogen (TN, mg N/mg beef (control)), dry weight basis.
M = Percent total nitrogen (% TN), dry weight basis.
N = Low ionic strength (LIS) soluble protein fraction (mg N/mg beef (control)), dry weight basis.
O = Non-protein nitrogen (NPN) extract (mg N/mg beef (control)), dry weight basis.
P = "Sarcoplasmic" protein fraction (LIS-NPN) (mg N/mg beef (control)), dry weight basis.
Q = "Remaining" protein fraction (TN - (LIS + NPN)) (mg N/mg beef (control)), dry weight basis.

(a) This is from the computer file called "TCAWD1" - output from the TCA program.

Table D.21. Data file (a) for prerigor pressurized ("treated") beef. Initial weights, cooking data, heating rates and cooking times, with cooking temperature-endpoint temperatures (CT-ET) for the central composite rotatable design (CCRD).

A	B	C	D	E	F(b)	G	H	I	J	K	L	M
2	083		322*	85.8	85.477	.9090	.9774	38.726	2.574	36.152	.011434	79.50
2	083	R	322	85.8	89.611	.9106	1.0611	38.523	.335	38.188	.011841	76.90
2	182		428*	85.6	88.448	.8559	1.5481	38.750	1.470	37.280	.017502	48.90
2	182	R	428	85.5	83.482	.9643	1.6345	38.977	.719	38.258	.019579	49.25
2	231		450*	74.9	77.477	.8390	2.8698	25.701	1.549	24.152	.037040	22.65
2	231	R	450	75.1	83.596	.8481	2.4877	31.572	.718	30.854	.029759	28.50
2	305		300*	74.9	80.744	.8050	1.0484	30.942	1.734	29.208	.012984	62.00
2	305	R	300	74.9	85.231	.8295	.9452	36.240	.469	35.771	.011090	74.80
2	345		375*	60.3	83.975	.6002	2.6047	15.624	.953	14.671	.031017	19.35
2	345	R	375	60.0	82.211	.6787	2.4911	20.663	.487	20.176	.030301	22.40
2	455		322*	64.5	83.492	.6767	1.9316	18.866	2.156	21.022	.023135	29.25
2	455	R	322	64.6	83.448	.7238	2.0475	23.401	1.438	21.963	.024536	29.50
2	707		375*	90.0	78.917	1.0150	1.3024	41.289	1.647	39.642	.016504	61.50
2	707	R	375	92.0	82.364	1.0563	1.4684	40.894	.728	40.166	.017828	59.25
2	976		428	66.1	80.113	.7028	2.2520	23.580	4.119	19.461	.028110	25.00
2	976	R	428*	64.8	83.513	.7256	2.8186	23.489	1.197	22.292	.033750	21.50
2	186	1	375*	74.9	83.023	.8058	2.0972	30.594	3.493	27.101	.025260	31.90
2	186	R1	375	74.9	86.423	.8181	1.6160	33.424	.579	32.845	.018699	43.75
2	577	2	375*	75.0	87.145	.7677	1.8081	28.803	1.377	27.426	.020748	37.00
2	577	R2	375	74.9	82.697	.8549	1.8364	33.617	.967	32.650	.022206	38.50
2	779	3	375	74.9	82.675	.7874	1.7595	27.197	3.145	24.052	.021282	37.00
2	779	R3	375*	75.1	83.869	.8454	1.7725	31.350	.954	30.396	.021134	40.00
2	113	4	375*	74.9	85.720	.7583	1.9432	28.107	3.383	24.724	.022669	33.45
2	113	R4	375	75.0	84.997	.8330	2.0990	29.823	1.529	28.294	.024695	33.73
2	104	5	375*	74.5	80.391	.8272	1.9000	31.189	3.856	27.333	.023634	35.00
2	104	R5	375	74.9	86.507	.8080	1.8156	31.323	.809	30.514	.020988	38.50

A = Species, beef (treated).
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points and further informational letters (R = repeat).
D = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Initial weight (g).
G = Heating rate (deg C/g).
H = Heating rate (deg C/min).
I = Cooking loss (total cooking loss, %).
J = Cooking loss (drip loss, %).
K = Cooking loss (evaporation loss, %).
L = Heating rate (deg C/g/min).
M = Cooking time (min).

(a) The order as given above is identical to the order used in the data file and the regression files called "STRAW2" - output from MDIST program.
Duplicate data sets are available, and "double" regression was performed on them.

(b) F is a dummy variable used for checking transcribing of data and analysis of variance table results.

Table D.22. Data file (a) for prerigor pressurized ("treated") beef. Mean values of expressible moisture index (EMI), percent total moisture, proteolytic enzyme values, cooking data, heating rates, cooking times, enzyme weight used.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O(b)	P	Q	R	S	T	U	V(b)
2	083		322	85.8	.308	55.182	38.726	2.574	36.152	.9090	.9774	.011434	79.50	85.477	.015	.025	.010	5.470		3.350	14.904
2	182		428	85.6	.262	57.840	38.750	1.470	37.280	.8559	1.5481	.017502	48.90	88.448	.023	.029	.006	5.431			14.914
2	231		450	74.9	.199	63.570	25.701	1.549	24.152	.8390	2.8698	.037040	22.65	77.477	.123	.135	.012	5.656		3.650	15.078
2	305		300	74.9	.246	62.164	30.942	1.734	29.208	.8050	1.0484	.012984	62.00	80.744	.035	.049	.014	5.685		3.400	14.988
2	345		375	60.3	.234	68.846	15.624	.953	14.671	.6002	2.6047	.031017	19.35	83.975	.423	.456	.033	5.546		2.550	14.973
2	455		322	64.5	.213	67.839	18.866	2.156	16.710	.6767	1.9316	.023135	29.25	83.492	.424	.456	.032	5.538		2.525	14.999
2	707		375	90.0	.264	58.557	41.289	1.647	39.642	1.0150	1.3024	.016504	61.50	78.917	.030	.038	.008	5.646		2.425	15.000
2	976	R	428	66.1	.235	65.636	23.489	1.197	22.292	.7256	2.8186	.033750	21.50	83.513	.144	.161	.017	4.388		3.200	15.026
2	186	1	375	74.9	.266	63.341	30.594	3.493	27.101	.8058	2.0972	.025260	31.90	83.023	.046	.051	.005	5.448		3.350	14.998
2	577	2	375	75.0	.252	59.464	28.803	1.377	27.426	.7677	1.8081	.020748	37.00	87.145	.048	.052	.004	5.479		3.000	14.975
2	779	R3	375	74.9	.237	60.273	31.350	.954	30.396	.8454	1.7725	.021134	40.00	83.869	.059	.072	.013	4.496		2.300	14.981
2	113	4	375	74.9	.231	59.735	28.107	3.383	24.724	.7583	1.9432	.022669	33.45	85.720	.059	.070	.011	5.595		2.750	15.090
2	104	5	375	74.5	.249	64.482	31.189	3.856	27.333	.8272	1.9000	.023634	35.00	80.391	.045	.050	.005	5.532		4.650	15.154

A = Species, beef (treated).
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points and further informational letters (R = repeat).
D = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Expressible moisture index (EMI).
G = Percent total moisture (% TM).
H = Cooking loss (total cooking loss, %)
I = Cooking loss (drip loss, %).
J = Cooking loss (evaporation loss, %).
K = Heating rate (deg C/g).
L = Heating rate (deg C/min).
M = Heating rate (deg C/g/min).
N = Cooking time (min).
O = Initial weight (g).
P = Proteolytic enzyme activity (at 0 deg C) (absorbance at 520 nm).
Q = Proteolytic enzyme activity (at 37 deg C) (absorbance at 520 nm).
R = Proteolytic enzyme activity difference (37 deg C - 0 deg C) (absorbance at 520 nm).
S = pH of beef (treated) and redistilled water slurry.
T = pH of extract, after enzyme removal.
U = Warner-Bratzler shear values (kg/127 mm diameter core).
V = Enzyme weight (g).

(a) This is from the computer file called "PHENZ2" but the cooking loss data, heating rates, initial weight and cooking time were previously obtained from "STRAW2".

(b) O and V are dummy variables used for checking transcribing of data and analysis of variance table results.

Table D.23. Data file (a) for prerigor pressurized ("treated") beef. Mean values of total nitrogen, Low Ionic Strength (LIS) protein solubility extract, non-protein nitrogen (NPN) extract, "sarcoplasmic" protein fraction and "remaining" protein fraction.

A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
2	083		322	85.8	.052704	5.270400	.002872	.003247	-.000375	.046586	.117596	11.759600	.006408	.007244	-.000836	.103944
2	182		428	85.6	.053793	5.379300	.002872	.003398	-.000526	.047523	.127591	12.759100	.006813	.008060	-.001247	.112719
2	231		450	74.9	.043049	4.304900	.003503	.003044	.000460	.036502	.118170	11.817000	.009617	.008355	.001262	.100199
2	305		300	74.9	.048263	4.826300				.048263	.127557	12.755700				.127557
2	345		375	60.3	.035724	3.572400	.005198	.002651	.002547	.027875	.114669	11.466900	.016685	.008509	.008177	.089475
2	455		322	64.5	.039148	3.914800	.004979	.003518	.001461	.030651	.121725	12.172500	.015482	.010938	.004544	.095305
2	707		375	90.0	.048510	4.851000	.002886	.001554	.001333	.044070	.117053	11.705300	.006965	.003749	.003216	.106339
2	976	R	428	66.1	.045952	4.595200	.003275	.003422	-.000147	.039255	.132763	13.276300	.009462	.009887	-.000425	.113413
2	186	1	375	74.9	.046882	4.688200	.003745	.003322	.000423	.039816	.127887	12.788700	.010214	.009062	.001153	.108611
2	577	2	375	75.0	.045635	4.563500	.002595	.003515	-.000920	.039525	.112580	11.258000	.006403	.008672	-.002269	.097506
2	779	R3	375	74.9	.046664	4.666400	.003568	.002231	.001337	.040865	.117461	11.746100	.008981	.005616	.003365	.102864
2	113	4	375	74.9	.043619	4.361900	.004468	.001575	.002893	.037575	.108329	10.832900	.011097	.003912	.007185	.093320
2	104	5	375	74.5	.049912	4.991200	.003511	.003707	-.000196	.042693	.140527	14.052700	.009885	.010438	-.000553	.120203

A = Species, beef (treated).
B = Three-digit code.
C = Central composite rotatable design (CCRD) center points and further informational letters (R = repeat).
D = Cooking temperature (deg F).
E = Endpoint temperature (deg C).
F = Total nitrogen (TN, mg Nitrogen/mg beef (treated)), wet weight basis.
G = Percent total nitrogen (% TN), wet weight basis.
H = Low ionic strength (LIS) soluble protein fraction (mg N/mg beef (treated)), wet weight basis.
I = Non-protein nitrogen (NPN) extract (mg N/mg beef (treated)), wet weight basis.
J = "Sarcoplasmic" protein fraction (LIS-NPN) (mg N/mg beef (treated)), wet weight basis.
K = "Remaining" protein fraction (TN -(LIS + NPN)) (mg N/mg beef (treated)), wet weight basis.
L = Total nitrogen (TN, mg N/mg beef (treated)), dry weight basis.
M = Percent total nitrogen (% TN), dry weight basis.
N = Low ionic strength (LIS) soluble protein fraction (mg N/mg beef (treated)), dry weight basis.
O = Non-protein nitrogen (NPN) extract (mg N/mg beef (treated)), dry weight basis.
P = "Sarcoplasmic" protein fraction (LIS-NPN) (mg N/mg beef (treated)), dry weight basis.
Q = "Remaining" protein fraction (TN - (LIS + NPN)) (mg N/mg beef (treated)), dry weight basis.

(a) This is from the computer file called "TCAWD2" - output from the TCA program.