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Algin/Calcium Gels in Solid-Muscle Structured Beef Steaks

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ALGIN/CALCIUM GELS

IN

SOLID-MUSCLE STRUCTURED BEEF STEAKS

BY

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This dissertation is approved as a creditable and independent investigation by a candidate for the degree, Doctor of Philosophy, and is acceptable for meeting the dissertation requirements of this degree. Acceptance of this dissertation does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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ALGIN/CALCIUM GELS IN SOLID-MUSCLE STRUCTURED BEEF STEAKS

Abstract

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Alteration of the inherent characteristics of less preferred beef carcass portions to produce products with greater consumer appeal has been the ultimate goal of structured meat research. Consumer acceptance of structured products has been limited because of (1) low retail visibility, (2) diet/health concerns due to salt addition, and (3) undesirable uncooked product appearance due to discoloration and lack of fiber orientation. Development of solid-muscle structured products would alleviate these limitations and the negative influence the less desirable carcass portions have on total carcass value.

Efficacy of a binding gel containing various concentrations of algin/calcium (Alg/Ca) and adipic acid (Ad) that will function between large meat pieces in both raw, refrigerated and cooked states was determined. Results indicated large muscle pieces could be bound by Alg/Ca/Ad gels in both states. Optimum levels could not be recommended since juncture success and binding strength were maximized at the highest Alg/Ca levels and

Ad levels used had no effect on these two traits.

In the second phase, consumer acceptability of four types of beef steaks fabricated from various muscles in the forequarter were measured. Steak types included (1) ribeye roll steaks, (2) serratus ventralis solid-muscle structured steaks, (3) salt/phosphate comminuted structured steaks, and (4) algin/calcium comminuted structured steaks. Primary meat purchasers rated each type of uncooked steak on fat content, surface discoloration, color and overall desirability. Each household member over 5 years old completed a sensory evaluation, rating each steak type for tenderness, juiciness, flavor desirability and overall desirability. Laboratory evaluations included proximate analyses, cooking loss, Warner-Bratzler shear and oxidative rancidity after frozen storage. Consumer sensory acceptability was evident for all four steak types, but primary meat purchasers preferred the color, lack of surface discoloration and overall appearance of intact muscle steaks over comminuted structured steaks. Intact muscle steaks received lower sensory tenderness ratings and higher flavor desirability scores than comminuted structured steaks. Viable merchandising options for the beef forequarter, particularly the chuck, are available with new structuring technology.

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INTRODUCTION

Current lifestyles dictate the preferred meat cuts are those which are easily prepared and provide a high degree of eating satisfaction while remaining within the budgetary restraints of the household (Burke Marketing Research, 1987). During the past 20 years, innovative marketing alternatives have been proposed by researchers to the meat industry in an attempt to satisfy consumer demands. Technological developments which utilize less valuable carcasses (cows and bulls) and carcass components (plates, flanks, shanks, etc.) to produce new products that provide satisfactory eating qualities at a reasonable unit cost have transpired (Seideman and Durland, 1982). Conversion of the less preferred carcasses and carcass portions into ready-to-cook products has been the value enhancement basis of structured[1] meat products (Breidenstein, 1982). The concept of structured meat products is to create a uniform and completely edible product which resembles an intact muscle in textural properties.

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[1] Structured and restructured are synonymous terms for the manufacturing technique described. However, due to the negative connotations associated with the term restructured, the term structured or derivatives of it will be used exclusively henceforth.

Breidenstein (1982) defined structured beef products as intermediate value beef products which are assumed to have a consumer perceived value between that of ground beef and intact muscle steaks and roasts normally prepared by dry heat. The primary production goal of structuring techniques is to control the shape, weight, fat and protein composition, and texture of the end-product during manufacturing. Furthermore, it is essential for the new products to possess integrity characteristics similar to intact muscle and uniform juiciness and tenderness (Mandigo, 1982).

Traditional structured meat production systems involve two primary steps: (1) reduction of particle size in the raw meat material and (2) binding together of these meat pieces to produce a unit system. Particle size reduction of the raw material is usually the first step in the structuring process and has been accomplished by numerous techniques--including grinding, flaking, chunking and sectioning of the raw material prior to forming (Huffman and Cordray, 1982). The primary objective of these techniques is to enhance the tenderness profile of the muscle tissue without reducing the textural properties of the muscle tissue to that of ground beef.

Structuring of meat products is based upon the ability to bind small meat pieces together. During the 1970's and early 1980's, adhesion in the uncooked state was achieved by freezing and was dependent upon heat induced bonding in the cooked state. Typically, adhesion at the particle interfaces was initiated by mechanical formation of a protein exudate by extraction of intracellular proteins, especially myosin, to the particle surfaces. Extraction was accomplished by stirring/mixing/massaging and enhanced by the presence of sodium chloride and phosphates (Breidenstein, 1982). During thermal processing, the protein exudate undergoes gelation--the denaturation of the protein molecules into unfolded polypeptides and the subsequent association of the polypeptides into a gel matrix (Ferri, 1948). The three-dimensional matrices formed by hydrogen bonds, disulfide bonds, hydrophobic association, or a combination of these between the polypeptides (Catsimpoolas and Meyer, 1970) hold water in the interstices (Kinsella, 1976) and act as a stable binder between meat chunks (Schmidt et al., 1981).

The efficacy of structuring technology developed during the 1970's and early 1980's has been limited due to the fact the products which were created did not meet consumer expectations. Retail acceptance of structured

products has been poor for several reasons:

(1) The products were offered only in a frozen form.

(2) The addition of salt, particularly sodium, provoked diet/health concerns (IFT, 1980; Pearson and Wolzak, 1982).

(3) The addition of salt had an adverse effect on color acceptability and rancidity development of fresh and frozen product (Schwartz and Mandigo, 1976; Ockerman and Organisciak, 1979; Huffman, 1980; Allen and Foegeding, 1981; Booren et al., 1981a; Chastain et al., 1982; Love, 1983).

(4) Product appearance has been less than desirable due to the lack of fiber orientation.

In an extensive literature review of raw and cooked meat binding, Means (1985) identified several compounds, particularly the in situ myosin system, that possessed desirable binding characteristics in the cooked state. However, only two compounds, gelatin and algin/calcium, were functional raw binders, and only algin/calcium was thermostable and capable of maintaining product integrity during cooking. Thus, in response to the first three previously defined

shortcomings of structured meat products, Means (1985) conducted a project which resulted in the development of a sodium alginate and calcium carbonate binding mechanism for structured beef steaks which would eliminate the need for the addition of salt and function in both the raw, refrigerated state and the cooked product. Since its development, the process has been patented (Schmidt and Means, 1986) and approved for commercial production (USDA/FSIS, 1986).

The algin/calcium binding system patented by Schmidt and Means (1986) is based upon the gelation capabilities of the polysaccharide hydrocolloid. When compared to other gel forming hydrocolloids, gelation of alginate is unique since the reaction is chemically rather the thermally induced. Alginic acid and its various inorganic salt forms, referred to as algin and alginate, respectively, are linear polysaccharides composed of D-mannuronic acid (M-block regions) and L-guluronic acid (G-block regions; McDowell, 1977; Morris et al., 1977; Rees and Welsh, 1977; Cottrell and Kovacs, 1980; Morris et al., 1980; Glicksman, 1982; Sand, 1982). Alginate gels are formed by intermolecular association of polyvalent cations (except magnesium) with predominately G-block regions of the polysaccharide molecules. Calcium ions, the most commonly used source

of cations in food systems, are superior to other polyvalent cations in their interaction with alginate (McDowell, 1966; Cottrell and Kovacs, 1980; Sanderson, 1981; Glicksman, 1982).

Value enhancement of carcass portions that are currently deemed to be of relatively limited value is the basis for selecting raw materials for structuring (Breidenstein, 1982). Depressed consumer demand for traditional chuck roasts and steaks has forced the beef chuck to the forefront as a potential source of raw material for structured beef products. Seideman (1982) indicated that, if structured steaks were to be produced from the muscles of the chuck, a means of degrading or removing connective tissue was needed so that the meat would not have to be so finely flaked or comminuted. Breidenstein (1982) advised that caution must be exercised in the manufacture of structured products when using raw materials which have heavy concentrations of connective tissue embedded in the muscle mass.

Depressed consumer demand for traditional beef chuck roasts and steaks has been attributed to compositional differences related to intermuscular fat quantities and wide variations in palatability of the numerous muscles present (Paterson and Parrish, 1986).

Until recently, minimal baseline information was available on the inherent characteristics of the beef chuck and/or a majority of the individual muscles that are present. Characterization studies of the muscles in the chuck (McKeith et al., 1985; Paterson and Parrish, 1986; Choi et al., 1987) and the forequarter (Johnson et al., 1988a) have suggested that certain muscles may best be utilized if removed and marketed separately.

In an extensive characterization study of the forequarter performed at South Dakota State University, Johnson et al. (1988a) reported the serratus ventralis (SRV) muscle, located primarily in the chuck, was the largest muscle in the forequarter and possessed a tenderness profile comparable to the longissimus dorsi. These tenderness evaluation results were in agreement with those presented by Smith et al. (1978), Paterson and Parrish (1986) and Choi et al. (1987). Moreover, the SDSU characterization study found SRV to be relatively free of internal connective tissue seams when compared to the other major muscles of the chuck (infraspinatus and the triceps brachii complex). Although SRV was found to be the largest muscle in the forequarter and/or chuck, the thickness of SRV did not appear to be conducive to the production of consumer desired steaks. However, because of the fan-like shape

of SRV, it appeared feasible to stack and bind two SRV's together and subsequently cut steaks from the muscle mass.

The goal of this research was to develop a new generation of structured beef products which (1) could be marketed in the raw, refrigerated state and maintain integrity during cooking; (2) contained no salt, and (3) possessed the traditional steak appearance because of desirable fiber orientation. Specific objectives of this project included:

(1) Development of a binder utilizing algin/calcium which could adhesively fuse whole muscles.

(2) Evaluation of the consumer acceptability of solid-muscle structured serratus ventralis steaks.

(3) Comparison of the sensory, physical and chemical characteristics of solid-muscle structured serratus ventralis steaks with intact rib eye steaks and comminuted structured steaks.

Upon realization of these research objectives, a solid-muscle structured beef product would be developed that would possess traits comparable to many consumer preferred beef steaks. The extension of beef product

lines to include this type of product for the consumer would enhance the value of the beef carcass at all levels within the industry.

Chapter II.

EFFECT OF ALGIN/CALCIUM AND ADIPIC ACID CONCENTRATIONS ON MUSCLE-JUNCTURE FORMATION

Introduction

Traditionally, the binding phenomenon between meat chunks in structured products has been achieved through heat-set gels formed by muscle or non-muscle proteins, regardless of production methodology and/or meat particle size (Breidenstein, 1982). Recently, a binding system utilizing the hydrocolloid alginate was patented (Schmidt and Means, 1986) and approved for commercial production (USDA/FSIS, 1986) capable of binding comminuted structured products in both the raw, refrigerated form and the cooked state. The newly developed binding system (Schmidt and Means, 1986) utilizes the ability of alginate to form instantaneous gels by reacting with calcium salts. The availability of free calcium ions controls the development of the chemically-induced algin/calcium gel, and calcium ion availability depends on the solubility of the calcium salt used and the pH of the solution (Cottrell and Kovacs, 1980; Glicksman, 1982).

Attempts to duplicate the textural properties of intact muscle and enhance sensory perception of

structured meat products resulted in the adaptation of cured meat technology (Schmidt, 1978; Addis and Schanus, 1979) in the production of structured products from large muscle pieces, i.e. sectioned and formed products (Dalton, 1979; Huffman and Cordray, 1979; Booren et al., 1981a,b,c, 1982). Although the newly developed binding system of Schmidt and Means (1986) has been used successfully in comminuted products, evaluations of sectioned and formed structured products bound by the hydrocolloid system have not been performed.

Hydrocolloids are known to possess numerous functional properties that make them useful in food applications in addition to gelation capabilities. One such property is the adhesive quality of hydrocolloids due to their high affinity for water and their ability to interact with proteins and lipids commonly found in food (Glicksman, 1982). The current paper addresses the development of structured products from intact muscle systems bound by the adhesive properties of an algin/calcium gel.

Formation of a cohesive matrix in structured meat products depends on the binding forces between meat chunks. Binding strength is defined as the force per unit cross-sectional area required to pull apart bound pieces of meat and includes a measure of both the

cohesive force exerted between the binding matrix and the meat pieces and the strength of the binding matrix itself (Schmidt and Trout, 1984). In order to reduce costs while providing valuable insights into the processes involved, model systems have been used to evaluate the binding strengths of isolated muscle proteins (Samejima et al., 1969; Macfarlane et al., 1977; Siegel and Schmidt, 1979a,b), non-muscle protein additives (Siegel et al., 1979; Terrell et al., 1982) and algin/calcium gels (Means and Schmidt, 1986; Means et al., 1987). The objective of this experiment was to use a model system to evaluate the effectiveness of the algin/calcium gel as an adhesive binder in structured beef steaks.

Materials and Methods

A randomized complete block design was used to study the binding strength of algin/calcium/adipic acid gels between two meat blocks in both raw and cooked states. Treatments were arranged factorially (Table 1) with five levels of sodium alginate/calcium carbonate (ALG; Manugel DMB, Kelco, San Diego, CA; and CA; Gamma Sperse 80, Georgia Marble Co., Tate, GA, respectively) and three levels of encapsulated adipic acid (AD; CAP-SHURE® A-M100-70, Balchem Corp., Slate Hill, NY).

Table 1 - Variables and experimental design

Treatment code[a]	Ingredients and level (%) ALG[b]	CA[c]	AD[d]
I-L	2.00	0.360	80
I-M	2.00	0.360	100
I-H	2.00	0.360	120
II-L	2.25	0.405	80
II-M	2.25	0.405	100
II-H	2.25	0.405	120
III-L	2.50	0.450	80
III-M	2.50	0.450	100
III-H	2.50	0.450	120
IV-L	2.75	0.495	80
IV-M	2.75	0.495	100
IV-H	2.75	0.495	120
V-L	3.00	0.540	80
V-M	3.00	0.540	100
V-H	3.00	0.540	120

[a] Roman numeral of treatment code refers to sodium alginate/calcium carbonate level and letter is adipic acid level (low, medium, high).

[b] ALG = sodium alginate, percent of a 30 ml (w/v) distilled water solution.

[c] CA = calcium carbonate, percent of a 30 ml (w/v) distilled water solution.

[d] AD = adipic acid, percent of optimum adipic acid to calcium ion ratio.

Levels of ALG and CA were chosen based on the ideal algin to calcium ion ratio (2.5:0.18) and $CaCO_3$ solubility (Anonymous, 1984). Adipic acid levels were based on the theoretically ideal AD to calcium ion ratio (0.5:1.0) needed to achieve complete $CaCO_3$ ionization. The study was repeated in its entirety five times to give five complete replicates.

Fresh (2-day postmortem) beef inside rounds (M. semimembranosus and M. adductor from USDA Choice carcasses, John Morrell and Co., Sioux Falls, SD) were defatted, cut into blocks 4 cm x 8 cm x 8 cm and tumbled (VORTRON Model #250; E-Zuber Engineering, Inc., Minneapolis, MN) for 1 min (4 rev) to insure total randomization. Immediately following tumbling, meat blocks were paired and a 0.1 cm x 8 cm x 8 cm slice was cut with a deli-style slicer (Hobart Manufacturing Co., Troy, OH) from the contact surface of each block and placed in a labeled Whirl-Pak bag for subsequent raw pH determinations.

For each pair of meat blocks, AD was mixed with a spatula into 30 ml of prechilled ALG/CA solution for 30 sec. The gel solution was immediately spread with a spatula on the contact surface of the first meat block held in a plexiglass mold (8 cm x 8 cm x 15 cm). The second meat block was then introduced into the mold and brought into contact with the ALG/CA/AD solution. Care was taken during this step to (1) assure the muscle fibers of both blocks were parallel, (2) eliminate any visible air pockets trapped in the binding zone, and (3) minimize the loss of binding gel from the central regions due to extreme pressure.

Following a 20-hr set-up period at 4± 1°C, meat

blocks were cut with a knife transverse to the muscle fibers with the aid of a plexiglass mold into 12 - 1.5 cm x 4 cm x 8 cm steakettes. From the eight center steakettes of each meat block, four steakettes were randomly selected for raw bind evaluation. The other four center steakettes were used for cooked evaluation. Minimum and maximum gel thickness measurements were taken on each steakette immediately following cutting and removal of extraneous gel along the edges. Gel thickness was recorded as an average of these two measurements for each steakette.

Steakettes for cooked evaluation were grilled on Farberware open hearth electric broilers (average temperature at steak surface = 160-170° C). Steakettes were cooked for a constant time (5 min and 4 min per side; AMSA, 1978) to a medium-rare degree of doneness as judged by standard color photographs (NLS & MB, 1979). Cook yield was determined on each steakette as follows:

$$\text{Cook yield (\%)} = \frac{\text{Cooked steakette weight}}{\text{Raw steakette weight}} * 100\%$$

Subjective assessment of raw and cooked steakette juncture success was performed prior to objective measurement of binding strength. Junctures were classified as successful if the junctures remained

intact during handling of the steakettes in preparation for the objective measurement of binding strength.

Binding strength was determined with a Thwing-Albert (Model 65TM; Philadelphia, PA) Tensile Tester with crosshead speed of 1 mm/sec and equipped with a 2-kg tension load cell and spring-loaded grips. Peak force (g force/5 cm^2 juncture interface) required to separate each steakette at the binding junction was recorded for those steakettes which had successful junctures. Cooked steakettes were allowed to equilibrate to room temperature before peak force evaluation.

Raw pH was determined in duplicate by blending 5 g of meat sample removed prior to gel application with 50 ml of distilled water in a Waring Blendor for 20 sec. Hydrogen ion concentration of the meat slurries was determined with a Beckman (Model pHI 41) pH meter in conjunction with a Beckman combination electrode. Following cooked binding strength measurements, cooked steakettes were divided into thirds, with each third prepared for pH measurement in a manner similar to the raw sample procedure.

Raw and cooked juncture success data were analyzed using Chi-square analysis (Steele and Torrie, 1980). Continuous data were analyzed using general

linear model procedure(GLM)-least-squares analysis of variance (SAS, 1985). When significant differences were detected among treatment means, differences between means were determined by least significant difference (Steele and Torrie, 1980).

Results and Discussion

The main purpose of this investigation was to explore whether algin/calcium gels could be used as binding agents between large meat pieces in structured products. Previous use of algin/calcium gels in structured meat products has utilized the gelation capabilities of the system to form a cohesive matrix (Schmidt and Means, 1986). In contrast, efficacy of the current application of the algin/calcium gel is contingent upon the adhesive qualities of the gel.

Control of the chemically-induced gelation of algin and calcium may be accomplished by numerous techniques, including the solubility of the calcium salt used and the pH of the solution (Cottrell and Kovacs, 1980; Glicksman, 1982). Since $CaCO_3$ is relatively insoluble in cold water (CRC, 1972; Anonymous, 1984), alteration of the algin/calcium solution pH was used to control the ionization of $CaCO_3$ in the current application. One method of accomplishing this

algin/calcium solution pH alteration is through the addition of slowly released acids.

Although a slowly released acid was included in the patent disclosure (Schmidt and Means, 1986) and the commercial production approval (USDA/FSIS, 1986) for an algin/calcium binding agent, results of studies evaluating the benefits of this ingredient are inconclusive. Means (1985) stated the inclusion of the slowly released acid glucono-delta-lactone (GDL) may promote stronger binding of meat pieces by the algin/calcium gel in comminuted structured products. Results of preliminary studies conducted by Means et al. (1987) suggested the use of GDL may deter the undesirable flavor and mouthfeel of algin/calcium beef reported by Means and Schmidt (1986), both of which were attributed to the presence of unreacted Na-alginate. However, results reported by Means et al. (1987) showed the addition of GDL did not improve binding in the raw state or mouthfeel.

The lack of improvement in the physical and sensory traits of the algin/calcium structured products in the study conducted by Means et al. (1987) could possibly be explained by an insufficient alteration of the system pH to maximize calcium ion availability. The slowly released acid included by Means (1985) and Means

et al. (1987) was encapsulated in a partially hydrogenated vegetable oil, which has a melting point range of 57-62°C (Bielski, 1987). Thus, maximum pH alteration was not achieved until the product was cooked. Consequently, insufficient time was available for internal setting of the algin/calcium gel prior to sensory evaluation, possibly resulting in the presence of unreacted Na-alginate (Cottrell and Kovacs, 1980) and the detection of associated undesirable mouthfeel (Means and Schmidt, 1986).

Therefore, alteration of the algin/calcium solution pH in the current study was achieved through the use of a slowly released adipic acid encapsulated in a water soluble malto-dextrin coating (Bielski, 1987). Loss of the malto-dextrin coating upon introduction of the encapsulated adipic acid into the algin/calcium solution resulted in the gradual release of the adipic acid. The subsequent reduction of the gel solution pH was believed to enhance the gelation reaction, reducing the incidences of spot gelation and the presence of unreacted alginate, and thereby increase the adhesive qualities of the resulting gel.

Analyses of the paired meat block raw pH indicated a mean value of 5.3 with a range of 5.1 to 5.8. In addition, mean raw pH difference between the

paired meat blocks was 0.09 with a range of 0.0 to 0.30 (not presented in tabular form). No differences ($P>0.05$) were detected in any of the characteristics evaluated due to the interaction of ALG/CA and AD or the main effect of AD at the theoretically ideal level to achieve complete $CaCO_3$ ionization and at levels 20% above and below this ideal level. Therefore, mean values for all traits evaluated are reported by ALG/CA levels only.

Results of raw juncture success and binding strength of successfully bound steakettes are shown in Table 2. Raw juncture success increased as ALG/CA concentration increased. Chi-square analyses indicated no difference ($P>0.05$) between ALG/CA levels III, IV and V for raw steakette juncture success, but the success rate was greater ($P<0.01$) for these three groups than for levels I and II. Binding strength of raw steakettes was greatest ($P<0.05$) for those bound by ALG/CA level V, lowest ($P<0.05$) for ALG/CA levels I and II and intermediate for ALG/CA levels III and IV.

Cooked juncture success and binding strength results are presented in Table 3. Similar to the raw steakette results, juncture success increased as ALG/CA concentrations increased. Chi-square analyses indicated cooked juncture success was not different ($P>0.05$)

Table 2 - Effect of algin/calcium concentration on juncture success and binding strength of successfully bound raw steakettes

	ALG/CA[a]					
Trait	I	II	III	IV	V	SD[b]
Juncture success[c]	20	33	49	54	59	
Binding strength[d]	59[e]	60[e]	94[f]	91[f]	134	58.5

[a] ALG/CA = algin/calcium. See Table 1 for an explanation of treatment codes.
[b] Standard deviation.
[c] Successful junctures/60 steakettes.
[d] Peak force (g/5 cm^2) required to break successfully bound steakettes.
[e, f] Means with common superscripts do not differ ($P>0.05$).

between ALG/CA levels IV and V, but the success rate was greater ($P<0.01$) for these two groups than levels I, II and III. In addition, cooked juncture strength paralleled the cooked juncture success with ALG/CA level V numerically, but not statistically, the strongest gel.

Mean gel thickness was not different ($P>0.05$) for the five ALG/CA levels and ranged from 3.0 to 3.7 mm (Table 4). Since the desired gel thickness was between 2.0 and 2.5 mm, further investigations of this binding system should utilize less gel solution and an alternative technique to hold the product during the set-up period.

Table 3 - Effect of algin/calcium concentration on juncture success and binding strength of successfully bound cooked steakettes

	ALG/CA[a]					
Trait	I	II	III	IV	V	SD[b]
Juncture success[c]	7	13	29	46	50	
Binding strength[d]	86	103	127	147	193	81.6

[a] ALG/CA = algin/calcium. See Table 1 for an explanation of treatment codes.
[b] Standard deviation.
[c] Successful junctures/60 steakettes.
[d] Peak force (g/5 cm^2) required to break successfully bound steakettes.

Cook yield did not differ (P>0.05) between the five ALG/CA levels (Table 4). Previous use of the calcium alginate gelation mechanism to form a coating for refrigerated raw meat has resulted in a reduction in shrinkage (Earle, 1968). Uses of calcium alginate gel coatings as a deterrent to cooking losses have yielded mixed results (Williams et al., 1978; Wanstedt et al., 1981). Means and Schmidt (1986) did not find an improvement (P>0.05) in cook yield of structured beef steaks bound by the algin/calcium gel. The current application of the algin/calcium gelation reaction was such that no alterations of cooking loss were anticipated, due to the fact the algin/calcium gel was

Table 4 - Least-squares means for physical and chemical traits of algin/calcium bound steakettes

Trait	ALG/CA[a] I	II	III	IV	V	SE[b]
Gel thickness (mm)	3.7	3.1	3.0	3.4	3.4	0.39
SE[c]	0.22	0.18	0.17	0.18	0.17	
Cook yield (%)	84.8	84.3	84.7	84.6	83.1	0.84
SE[c]	0.58	0.65	0.69	0.94	0.64	
Cooked pH[d]						
Part 1	5.5[e]	5.5[e]	5.5[e]	5.5[e]	5.5[e]	0.01
Part 2	5.6[f]	5.6[f]	5.6[f]	5.6[f]	5.6[f]	0.01
Part 3	5.5[e]	5.5[e]	5.5[e]	5.5[e]	5.5[e]	0.01

[a] ALG/CA = algin/calcium. See Table 1 for an explanation of treatment codes.

[b] Standard error between treatment groups.

[c] Standard error within each treatment group.

[d] Parts 1 and 3 are the two end thirds of the cooked steakettes and Part 2 is the center third of the cooked steakettes. Orthogonal contrasts were made between Part 1 and Part 3 and between Parts 1 and 3 vs Part 2.

[e, f] Means within a treatment column with a common superscript do not differ (P>0.05).

applied as an internal seam for the product and not as a surface coating.

Cooked pH evaluations indicated the center third of the steakettes had a higher (P<0.05) pH than the end thirds, which were not different (P>0.05) from each other (Table 4). The addition of the Na-alginate and $CaCO_3$ led to the pH increase of the center region of the

steakettes. Although AD inclusion did not improve ($P>0.05$) the adhesive binding characteristics of the ALG/CA gel, AD was believed to minimize the adverse alteration of cooked pH. Therefore, further investigations of this binding technique should be conscious of the possible adverse effects of Na-alginate and $CaCO_3$ to flavor perception and continue to evaluate all functional benefits from the addition of an encapsulated acidulant.

Conclusions

The ALG/CA/AD gel can be used as an adhesive binder in the production of structured beef steaks which bind not only in the cooked product, but also in the raw, refrigerated state. These results indicate that a binding layer 3-mm thick will achieve maximum juncture success in both the raw and cooked product when the gel solutions contain at least 2.75% ALG and 0.54% CA. The addition of AD was believed to enhance the binding characteristics of the ALG/CA gel and reduce the possible adverse effects that ALG and CA would have on the palatability traits of the products. Further research is necessary to determine if the levels of the three ingredients used to form the binding gel were optimized. Therefore, further projects should

investigate higher concentrations of the ALG/CA solution and broader ranges of the AD level.

Production of solid-muscle structured products using whole muscles bound by a thin layer of adhesive ALG/CA/AD binder would enhance consumer perception of structured meat products. Products produced by this technique would possess sensory advantages of sectioned and formed structured products and could be marketed in the raw, refrigerated state.

Chapter III.

SENSORY, CHEMICAL AND PHYSICAL CHARACTERISTICS OF FOUR TYPES OF BEEF STEAKS

Introduction

Structured meat products have been indicated as a viable method of enhancing the value of less preferred carcass portions (Breidenstein, 1982). Due to the high degree of variability in the cut-out yield and palatability characteristics of the numerous muscles present, the beef forequarter, particularly the chuck, has been viewed as a primary source of raw material for value-added beef products. Since traditional fabrication techniques result in the subdivision of several muscles within the chuck, previous structuring research has used the entire chuck as a lean source without any preference for the various muscles. However, recent characterization studies of the chuck muscles (McKeith et al., 1985; Paterson and Parrish, 1986; Choi et al., 1987; Johnson et al., 1988a) have suggested that certain muscles may best be utilized if marketed separately.

Structured meat technology has been based on the reduction of particle size or modification of the raw material, followed by blending and reforming to produce

ready-to-cook products (Breidenstein, 1982). Large scale adaptation of structuring technology by the meat industry has not occurred, due primarily to shortcomings in consumer eating satisfaction and retail market acceptance of structured products.

Attempts to duplicate the textural properties of intact muscle resulted in the adaptation of technology previously applied to cured meats (Schmidt, 1978; Addis and Schanus, 1979) and the evolution of sectioned and formed fresh structured meat products (Dalton, 1979; Huffman and Cordray, 1979; Booren et al., 1981a,b,c, 1982). Sensory evaluations have shown sectioned and formed steaks were more desirable than intact muscle or flaked and formed steaks (Booren et al., 1981b), and sectioned and formed pork chops were more tender than intact chops (Dalton, 1979; Huffman and Cordray, 1979). However, severe color problems have been found in the finished sectioned and formed products which have been attributed to color deterioration during processing (Booren et al., 1979, 1981b; Huffman and Cordray, 1979).

Until recently, structured meat products had to be marketed either frozen or precooked to retain structural integrity. The development of an algin/calcium binding system for comminuted structured products (Schmidt and Means, 1986; USDA/FSIS, 1986) and

large muscle pieces (Johnson et al., 1988b) have made it possible to present comminuted structured products to consumers in the raw, refrigerated state.

Limited research has been conducted on the consumer acceptance of structured beef steaks, particularly those steaks produced by the two algin/calcium binding techniques. Therefore, this study was performed to (1) determine the consumer acceptance of the two types of algin/calcium structured steaks, (2) compare comminuted structured steaks to intact muscle steaks, (3) compare solid-muscle structured serratus ventralis steaks to ribeye roll steaks, and (4) compare algin/calcium comminuted structured steaks to salt/phosphate comminuted structured steaks.

Materials and Methods

Experimental design

A complete block design was used to evaluate four types of steaks produced from various muscles within the beef forequarter. The four types of steaks--(1) ribeye roll steaks (RER), (2) serratus ventralis solid-muscle structured steaks (SRV), (3) salt/phosphate comminuted structured steaks ($NaCl/PO_4$), and (4) algin/calcium comminuted structured steaks (Alg/Ca)--were evaluated in the laboratory and by an in-home

consumer panel. Data were analyzed by analysis of variance using the general linear model(GLM)-least-squares program of the Statistical Analysis System (SAS, 1985). The entire procedure was repeated 10 times and individual animals were used as blocks to remove variation due to differences among animals from the error sum of squares (Neter and Wasserman, 1974). Sex and age of the individual evaluators were included as variables for the in-home data statistical analyses. Orthogonal contrasts were made for all traits evaluated between (1) intact muscle steaks (RER and SRV) vs comminuted structured steaks (NaCl/PO_4 and Alg/Ca), (2) RER vs SRV, and (3) NaCl/PO_4 vs Alg/Ca.

Raw material source

For each replication, both forequarters from a beef carcass which met the criteria listed in Table 5 were obtained 18-24 hr postmortem from a local packer (Huron Dressed Beef, Huron, SD) and transported to the South Dakota State University Meat Laboratory, Brookings. Forequarters were broken into wholesale cuts following the procedure outlined by NAMP (1980) and Romans et al. (1985).

Steak preparation

Wholesale ribs were processed into 112 ribeye rolls (NAMP, 1980), packaged in Cryovac® bags (Cryovac

Table 5 - Beef carcass selection criteria

Trait	Requirements
Sex	Heifer
Weight (kg)	290 - 340
Adj. fat thickness (cm)	0.95 - 1.00
Rib eye area (cm^2)	77 - 84
Bone maturity[a]	A
Marbling[b]	4.50 - 4.99
Lean color[a]	Cherry red

[a] Based on descriptions included in USDA (1975) beef grade standards.

[b] Coded: minimum slight = 4.00 and minimum small = 5.00.

Div., W.R. Grace & Co., Duncan, SC), which were evacuated and heat sealed using a chamber-type vacuum packaging machine (Multivac, type AG 500; Koch Supplies Inc., Kansas City, MO), and held at 5°C.

Serratus ventralis muscles were excised from both chucks and trimmed of surface fat following removal of the rib cage and thoracic and cervical vertebrae. Utilizing the technique developed by Johnson et al. (1988b) for binding two large muscle masses together, a solid-muscle meat block was produced from the two serratus ventralis muscles. The algin/calcium/adipic acid gel solution used as an adhesive binder between the two serratus ventralis muscles contained 3.33% Na-

alginate (Manugel DMB; Kelco, San Diego, CA), 0.60% $CaCO_3$ (Gamma Sperse 80; Georgia Marble Co., Tate, GA) and 0.624% encapsulated adipic acid (CAP-SHURE® A-M100-70; Balchem Corp., Slate Hill, NY). A planimeter (Tamaya Planix 5; The Lietz Co., Overland Park, KS) was used to determine muscle surface area (MSA) from an acetate tracing of the lateral surface of one serratus ventralis muscle. Quantity of prechilled algin/calcium gel solution (ml) necessary to obtain a binding gel thickness of 0.15 cm was calculated as follows:

$$\text{Gel solution (ml)} = \text{MSA}(cm^2) * 0.15\ cm * 1\ ml/cm^3$$

A spatula was used to incorporate the encapsulated adipic acid into the gel solution immediately prior to application and to spread the gel solution onto the muscle surface. Following application of the gel solution, the second serratus ventralis muscle was stacked on the first muscle in a manner which made the adhesive binder a plane of symmetry for the newly created muscle mass. The bound serratus ventralis muscles were vacuum packaged in Cryovac® bags and held at 5° C.

Remaining lean tissue of the wholesale chucks and 109B blade meat from the wholesale ribs (NAMP, 1980) were defatted and trimmed of visible connective

tissue and coarse ground through a kidney plate (Hobart Mixer-Grinder; Hobart Manufacturing Co., Troy, OH). Lean obtained from the wholesale brisket, plate and shank was excluded from the comminuted treatment groups. Six kg of the coarse ground lean were reground through a plate with 4.7 mm diameter openings to produce a fine ground fraction.

Ten-kg batches of each type of comminuted structured product ($NaCl/PO_4$ and Alg/Ca) were prepared from 8 kg coarse ground and 2 kg fine ground lean. Dry ingredients were added during the first 1 min of blending, and batches were mixed in a double-ribbon blender (Leland Food Mixer 100 DA; Leland Detroit Manufacturing Co., Detroit, MI) for 10.5 min in a 2°C cooler. The $NaCl/PO_4$ structured product was formulated to contain 1.4% sodium chloride and 0.32% sodium tripolyphosphate (FMC Corp., Philadelphia, PA). The Alg/Ca structured product was formulated to contain 0.55% Na-alginate (Manugel DMB), 0.10% $CaCO_3$ (Gamma Sperse 80) and 0.30% encapsulated lactic acid (CAP-SHURE® LCL-135-50; Balchem Corp., Slate Hill, NY). Upon completion of mixing, treatments were vacuum stuffed (VEMAG Robot 500; Robert Reiser & Co., Inc., Boston, MA) into Cryovac® bags (19 cm flat width), which were evacuated and heat sealed. The $NaCl/PO_4$ structured

product was frozen at -25°C and Alg/Ca structured product was held at 5°C.

After a 15-hr holding period, all treatment groups were cut into steaks (1.25 cm x ~5 cm x ~15 cm). Eight steaks were randomly selected from each treatment group and individually vacuum packaged in Cryovac® bags. Six of these steaks were frozen and stored at -25°C for subsequent laboratory evaluations. Two steaks were used for 1 d post-fabrication laboratory evaluations.

Steaks intended for the in-home evaluation were labeled with two numbered metal identification tags (0.95 cm x 3.65 cm Hasco Self-locking Tags; Nasco, Fort Atkinson, WI) placed in opposite ends of every steak. Each type of steak was individually packaged for delivery to the participating households, with the number of steaks in each package dependent upon the household composition (1 steak/treatment/2 people over 5 years old). Non-frozen treatment steaks (RER, SRV and Alg/Ca) were packaged in retail-type tray-pack which consisted of a styrofoam tray (Mobil Chemical, Packaging Department) overwrapped with permeable polyvinyl chloride (PVC), all-purpose, food film (PW-18, Anchor Industries). Frozen steaks ($NaCl/PO_4$) were packaged in Cryovac® bags which were evacuated and heat sealed.

Laboratory evaluations

On d 1 post-fabrication, two steaks from each treatment were trimmed of any remaining fat and visible epimysium, frozen in liquid nitrogen and homogenized in a stainless steel Waring blender. Duplicate samples from each steak were used for the determination of 2-Thiobarbituric acid (TBA) values (Tarladgis et al., 1960). Powdered steak samples were stored at -25°C no more than 3 wk until triplicate samples were used to determine moisture, fat and protein (AOAC, 1980). After 33 d of frozen storage (-25°C), two steaks from each type were allowed to thaw at 5°C for 24 hr, powdered by the previously described procedure and duplicate samples were used to determine TBA values. The TBA procedure was repeated on two additional steaks after 70 d of frozen storage (-25°C).

Within 3 wk of fabrication, steaks from the RER, SRV and Alg/Ca fabrication groups were allowed to thaw at 5°C for 24 hr prior to cooking loss determination and Warner-Bratzler shear (WBS) analysis. The $NaCl/PO_4$ steaks were not allowed to thaw prior to cooking. All steaks for cooking loss determination and WBS analysis were grilled on Farberware open hearth electric broilers (average temperature at steak surface = 160-170°C). Steaks were cooked for a constant time (RER, SRV and

Alg/Ca: 8 min and 7 min per side, and NaCl/PO_4: 13 min and 12 min per side; AMSA, 1978) to a medium-rare degree of doneness as judged by standard color photographs (NLS & MB, 1979). Cooking loss was determined on each steak as follows:

$$\text{Cooking loss (\%)} = \frac{\text{raw steak wt} - \text{cooked steak wt}}{\text{raw steak wt}} * 100\%$$

After the steaks had cooled to room temperature, six 1.27-cm diameter cores were removed from each steak perpendicular to the steak surface and a single WBS value was obtained for each core.

Consumer research design

The in-home consumer panel was composed of individuals from households which were classified as moderate/light or heavy users of fresh beef, excluding ground beef (Breidenstein and Williams, 1986). The in-home consumer evaluation was designed to obtain information about each type of steak prior to and during cooking in conjunction with sensory evaluations.

Preliminary identification of potential households was performed in 12 grocery stores in three eastern South Dakota cities during 1-hr time slots of heavy traffic periods (Thursday, 14:00-18:00 hr; Friday,

14:00-18:00 hr, or Saturday, 9:00-15:00). Steak section patrons were asked, after leaving the meat counter, if their household would be willing to participate in an in-home evaluation of four types of beef steaks which differed only in the fabrication technique used at no financial obligation. If the representative of the household agreed, a preliminary questionnaire (Appendix Figure 1) was completed requesting (1) address and telephone number, (2) name of the primary meat purchaser, (3) name of the primary cook, (4) frequency of fresh beef consumption, excluding ground beef, (5) most common cookery technique for steak items, (6) preferred degree of doneness for steak items, and (7) household composition by age groups (less than 5 years old, 5-15, 16-25, 26-35, 36-45, 46-55, 56-65, over 65 years old). During the initial contact, household representatives were informed of the requirements for participation, including completion and return of (1) a raw product evaluation by the primary meat purchaser, (2) a cooking evaluation by the primary cook, and (3) sensory evaluations by every household member over 5 years old.

Upon completion of the in-store contact and interview periods, potential households were further screened based on (1) frequency of fresh beef

consumption, (2) common cookery technique for steaks, and (3) household location.

Scheduling of product delivery and assignment of households to each replication was accomplished by random telephone calls to the households remaining after the screening process. Households were given an option of four possible delivery dates until the replication numbers were fulfilled (sensory evaluations/replication = 25-28 individuals over 5 years old). During the scheduling telephone call, verification was made of the household address, name of the primary meat purchaser and primary cook and composition of the household. In addition, simplified directions were obtained to the household to expedite delivery. Twenty-four hours prior to delivery, each household was telephoned again to confirm the delivery and give an approximate delivery time.

Steaks were delivered to the households 1 d post-fabrication, with each household receiving one package of each steak type with the appropriate number of steaks. In addition, each household was provided with an evaluation packet which contained general instructions (Appendix Figure 2) and color-coded evaluation forms for the primary meat purchaser (Blue Form, Appendix Figure 3), the primary cook (Green Form,

Appendix Figure 4), and a sensory evaluation form (Yellow Form, Appendix Figure 5) for each member of the household over 5 years old. Specific instructions for each evaluation form (Appendix Figures 3, 4 and 5), cooking time guidelines (Appendix Figure 4), a degree of doneness color guide (NLS & MB, 1979) and a self-addressed stamped envelope for return of the evaluation forms were also included in the evaluation packet. Household and steak identification numbers were listed on all evaluation forms prior to delivery. Names of the primary meat purchaser and primary cook were also indicated on the appropriate forms.

The Blue Form requested the primary meat purchaser to evaluate the packaged steaks before cooking for color desirability, fat content, overall desirability and surface discoloration. Numerical descriptive codes were given for color and overall desirability (1 = dislike extremely, 8 = like extremely) and fat content (1 = abundant, 2 = slightly abundant, 3 = moderate, 4 = modest, 5 = slight, 6 = traces, 7 = practically none, 8 = none). Surface discoloration was defined as the percentage (0-100%) of the steak surface area which was not normal beef color. The primary meat purchaser was also asked to indicate on a diagram for each type of steak the area(s) of major discoloration.

The Green Form asked the primary cook to indicate the cookery method used (broil in the home, broil outside the home or pan fry) and record a sample integrity score for each type of steak at the completion of cooking using the scale: 1 = more than 8 pieces, 2 = 7-8 pieces, 3 = 5-6 pieces, 4 = 3-4 pieces, 5 = 2 pieces, 6 = intact.

Degree of doneness, tenderness, juiciness, flavor desirability and overall desirability were evaluated by each household member over 5 years old and recorded on the Yellow Form with scores assigned by use of the following scales: degree of doneness (1 = very well done, 6 = very rare); tenderness (1 = extremely tough, 8 = extremely tender); juiciness (1 = extremely dry, 8 = extremely juicy); flavor desirability and overall desirability (1 = dislike extremely, 8 = like extremely).

Within 3 wk of delivery, a follow-up telephone call was made to each household to reiterate the importance of returning the completed evaluation forms and to collect additional demographic information (Appendix Figure 6). Demographic information obtained included educational background of the primary meat purchaser, occupation of the male and/or female head(s) of the household and household median income. Three

levels of education were used to categorize the primary meat purchasers: less than 9 yr, 9-12 yr or more than 12 yr. Three levels of yearly income were used to segment households: less than $15,000, $15,000-$39,999 or $40,000 and over.

Results and Discussion

Laboratory evaluations

The least-squares means for the chemical composition, cooking loss, WBS and TBA values of the four types of beef steaks are presented in Table 6. Intact muscle steaks had more ($P<0.05$) extractable fat than comminuted structured steaks, due primarily to higher fat content of SRV steaks. Cooking losses were greater ($P<0.01$) for intact muscle steaks as compared to comminuted steaks. The reduced cooking losses of the comminuted structured steaks can be attributed to the increased water binding capacity (WBC) due to the addition of salt and phosphate (Sofos, 1983; Schmidt and Trout, 1984; Trout and Schmidt, 1984) or alginate (Wanstedt et al., 1981).

Within the intact muscle steaks, SRV steaks were found to contain more ($P<0.01$) fat and less ($P<0.01$) protein than RER steaks (Table 6). Fat content of RER steaks was higher than previously reported fat

Table 6 - Least-squares means for laboratory evaluated traits[a]

Steak type[b]	Proximate analysis (%)			Cooking loss (%)	Warner-Bratzler shear (kg/1.27 cm)	TBA value (mg malonaldehyde/kg meat)		
	Moisture	Fat	Protein			Day 1	Day 33	Day 70
Intact muscle								
RER	72.8±0.42	5.3±0.45	19.6±0.23	19.5±0.22	3.9±0.08	0.23±0.02	0.20±0.02	0.26±0.03
SRV	73.0±0.47	7.7±0.63	17.5±0.30	23.0±0.26	4.6±0.14	0.25±0.02	0.24±0.01	0.38±0.06
Comminuted								
$NaCl/PO_4$	72.0±0.42	5.9±0.29	18.6±0.19	17.6±0.34	2.4±0.16	0.23±0.02	0.21±0.02	0.37±0.02
Alg/Ca	73.5±0.29	5.1±0.25	18.0±0.16	15.1±0.23	2.8±0.24	0.32±0.02	0.30±0.01	0.37±0.03
Orthogonal contrasts								
Intact muscle vs comminuted		*		**	**		**	
RER vs SRV		**	**	*			*	
$NaCl/PO_4$ vs Alg/Ca	*					**	**	

[a]Least-squares mean ± standard error for each trait within each steak type.

[b]RER = ribeye roll steak; SRV = serratus ventralis solid-muscle structured steak; $NaCl/PO_4$ = salt/phosphate comminuted structured steak; Alg/Ca = algin/calcium comminuted structured steak.

* $P<0.05$.

** $P<0.01$.

percentages for longissimus dorsi muscle obtained from beef carcasses with comparable marbling levels (Savell et al., 1986) and lower than fat percentages for longissimus dorsi and spinalis dorsi reported in a muscle characterization study by Johnson et al. (1988a). Previous characterization studies (Choi et al., 1987; Johnson et al., 1988a) have shown serratus ventralis muscle to have higher fat percentages than found in the current study, even though the USDA quality grade of the carcasses in all three studies was similar. Cooking loss was greater ($P<0.05$) for SRV steaks than RER steaks.

Although both types of comminuted structured steaks were formulated from muscle tissue which had been handled as one unit until the incorporation of the dry ingredients, Alg/Ca steaks were found to have greater ($P<0.05$) moisture content than NaCl/PO_4 steaks (Table 6). Results of the cooking loss determination indicated no difference ($P>0.05$) between Alg/Ca and NaCl/PO_4 steaks, even though the Alg/Ca steaks had higher ($P<0.05$) raw moisture contents. These results suggest the algin/calcium binding system has a greater WBC than the salt/phosphate binding system. Previous evaluations of the algin/calcium binding system (Means and Schmidt, 1986; Means et al., 1987) have reported no differences

in cook yield of algin/calcium and salt/phosphate structured steaks.

Intact muscle steaks were less ($P<0.01$) tender than comminuted structured steaks as measured by WBS (Table 6). The intent of comminution is to reduce the particle size of less tender muscles and therefore improve the perceived tenderness of the newly created product. Thus, use of a ground product in the formulation of comminuted structured steaks in the current study was beneficial.

Solid-muscle structured steaks produced from serratus ventralis muscles were numerically, but not statistically ($P>0.05$) less tender than RER steaks (Table 6). Previous characterization studies (Paterson and Parrish, 1986; Choi et al., 1987; Johnson et al., 1988a) have shown serratus ventralis, longissimus dorsi and spinalis dorsi muscles to be comparable in tenderness when the muscles have been aged.

Differences in TBA values for the four types of steaks, although statistically significant, were minimal at all evaluation times (Table 6). Steaks obtained from meat blocks which underwent extensive handling and fabrication (SRV, $NaCl/PO_4$ and Alg/Ca) had greater numerical increases in TBA values during the storage period than RER steaks. Extra handling of the product

during fabrication and addition of binding agents could explain the increased fat oxidation.

Consumer evaluations

A summary of the participating primary meat purchaser demographics is presented in Table 7. Almost 90% of the primary meat purchasers were over 26 years old and almost 64% were female. In addition, over 97% of the primary meat purchasers had more than 9 yr of education and 67.5% had more than 12 yr of education. Participating household and sensory panel member demographics are presented in Table 8. Household demographics indicated less than 8% of the households were classified as rural, farm, while over 80% were urban (U.S. Bureau of Census, 1980). Median income of over 92% of the households was greater than $15,000, and almost 30% of the households had median incomes greater than $40,000. Breakdown of sensory panel participants by age and sex showed nearly equal representation of males and females in all five age groups.

Age and sex of the primary meat purchaser and sensory panelists had no effect ($P>0.05$) on the scores given to the uncooked steak traits or on any of the sensory traits evaluated, respectively. Therefore, least-squares means and the predetermined orthogonal contrasts for the uncooked steak traits and the sensory

Table 7 - Summary of primary meat purchaser demographics[a]

	Male	Female	Total
Age			
Less than 26 yr	3 (3.9)	5 (6.5)	8 (10.4)
26 - 35 yr	9 (11.7)	13 (16.9)	22 (28.6)
36 - 45 yr	7 (9.1)	15 (19.5)	22 (28.6)
Over 45 yr	9 (11.7)	16 (20.8)	25 (32.5)
Total	28 (36.4)	49 (63.6)	77 (100.0)
Education			
Less than 9 yr			2 (2.6)
9 - 12 yr			23 (29.9)
More than 12 yr			52 (67.5)
Total			77 (100.0)

[a]Frequency of observations within age or education (percentage of total).

traits are presented by steak type only in Tables 9 and 10, respectively.

Intact muscle steaks received higher, more desirable ($P<0.01$) color scores from the primary meat purchasers than the comminuted structured steaks (Table 9). No differences ($P>0.05$) were detected between the two types of intact muscle steaks or between the two types of comminuted structured steaks. The RER steaks had the highest color rating and the frozen NaCl/PO_4 steaks had the lowest mean value. Surface discoloration

Table 8 - Summary of household demographics and sensory participant ages[a]

Location[b]	Total
Rural, farm	6 (7.8)
Rural, nonfarm	9 (11.7)
Urban	62 (80.5)
Total	77 (100.0)

Median Income	
Less than $15,000	6 (7.8)
$15,000 - $40,000	48 (62.3)
Over $40,000	23 (29.9)
Total	77 (100.0)

Sensory participant ages	Male	Female	
Less than 15 yr	18 (8.5)	25 (11.7)	43 (20.2)
16 - 25 yr	24 (11.3)	15 (7.0)	39 (18.3)
26 - 35 yr	20 (9.4)	22 (10.3)	42 (19.7)
36 - 45 yr	18 (8.5)	22 (10.3)	40 (18.8)
Over 45 yr	27 (12.7)	22 (10.3)	49 (23.0)
Total	107 (50.2)	106 (49.8)	213 (100.0)

[a] Frequency of observations within location, median income or age (percentage of total).

[b] Based on descriptions included in U.S. Bureau of Census (1980).

ratings paralleled the color desirability scores, with intact muscle steaks having less ($P<0.05$) surface discoloration than comminuted structured steaks. Discoloration of structured products has been attributed to the addition of NaCl by several other researchers

Table 9 - Least-squares means for primary meat purchaser evaluation of uncooked steak traits[a]

Steak type[b]	Color	Perceived fat content	Overall	Surface discoloration
Intact muscle				
RER	7.2±0.11	4.5±0.18	6.8±0.11	5.2±1.86
SRV	7.0±0.12	5.5±0.18	6.5±0.18	7.3±2.37
Comminuted				
$NaCl/PO_4$	6.2±0.19	5.5±0.16	6.1±0.17	15.3±3.11
Alg/Ca	6.4±0.20	5.8±0.17	6.2±0.19	13.2±2.97
Orthogonal contrasts				
Intact muscle vs comminuted	**	**	*	**
RER vs SRV		**		
$NaCl/PO_4$ vs Alg/Ca				

[a]Least-squares mean ± standard error for each trait within each steak type. Color and overall: 1 = dislike extremely and 8 = like extremely; fat content: 1 = abundant, 2 = slightly abundant, 3 = moderate, 4 = modest, 5 = slight, 6 = traces, 7 = practically none and 8 = none; surface discoloration: percentage of steak surface not normal beef color.

[b]RER = ribeye roll steak; SRV = serratus ventralis solid-muscle structured steak; $NaCl/PO_4$ = salt/phosphate comminuted structured steak; Alg/Ca = algin/calcium comminuted structured steak.

* $P<0.05$.

** $P<0.01$.

(Ockerman and Organisciak, 1979; Huffman, 1980; Booren et al., 1981b, Chastain et al., 1982, Means and Schmidt, 1986; Means et al., 1987). In contrast to the results of the current study, Means and Schmidt (1986) and Means et al. (1987) have observed no deleterious effects on surface discoloration of comminuted structured steaks due to the use of an algin/calcium binder.

Primary meat purchasers noted a greater ($P<0.01$) perceived fat content for intact muscle steaks than comminuted structured steaks (Table 9), primarily because of the perceived fat content of RER steaks. Although proximate analyses of the four types of beef steaks indicated RER steaks had the least amount of extractable fat (Table 6), perceived fat content of RER steaks was greater ($P<0.01$) than SRV steaks. Evaluation of the uncooked steaks by the primary meat purchaser took into account not only the intramuscular fat but also the intermuscular fat present. The more discernable fat content of RER steaks could possibly be explained since RER steaks were the only type evaluated which had intermuscular fat present.

Even though intact muscle steaks had more perceivable fat, intact muscle steaks received higher ($P<0.05$) overall desirability ratings (Table 9). These results suggest the negative effects of color

desirability and surface discoloration, or possibly the textural properties, of comminuted structured steaks were more detrimental to the primary meat purchasers' evaluation of uncooked steaks than intact muscle steak fat content.

Due to concern over the stability of the structured steaks prepared in this study when evaluated in a noncontrolled environment, the primary cook was asked to make an assessment of the integrity of all four types of steaks at the completion of cooking. Incidences of broken steaks were greatest ($P<0.05$) for SRV steaks (not presented in tabular form). However, since 15 of 70 households indicated RER steaks were in more than one piece after cooking, the validity of this portion of the study is questionable. Therefore, the results of the primary cook evaluation of steak integrity were not included in this discussion and use of this type of evaluation in future studies requires further consideration.

Sensory evaluations by each household member over 5 years old indicated no difference ($P>0.05$) between the intact muscle and comminuted structured steaks or within either pair of steak types for juiciness or overall desirability (Table 10).

Table 10 - Least-squares means for consumer evaluated sensory traits[a]

Steak type[b]	Tenderness	Juiciness	Flavor	Overall
Intact muscle				
RER	4.9±0.12	5.4±0.10	5.9±0.10	5.6±0.10
SRV	4.6±0.11	5.6±0.09	6.0±0.09	5.6±0.10
Comminuted				
$NaCl/PO_4$	6.0±0.11	5.3±0.11	5.6±0.12	5.6±0.12
Alg/Ca	6.5±0.10	5.5±0.10	5.5±0.13	5.6±0.13
Orthogonal contrasts				
Intact muscle vs comminuted	**		*	
RER vs SRV				
$NaCl/PO_4$ vs Alg/Ca				

[a]Least-squares mean ± standard error for each trait within each steak type. Tenderness: 1 = extremely tough and 8 = extremely tender; juiciness: 1 = extremely dry and 8 = extremely juicy; flavor and overall: 1 = dislike extremely and 8 = like extremely.

[b]RER = ribeye roll steak; SRV = serratus ventralis solid-muscle structured steak; $NaCl/PO_4$ = salt/phosphate comminuted structured steak; Alg/Ca = algin/calcium comminuted structured steak.

* $P<0.05$.

** $P<0.01$.

In agreement with WBS values (Table 6), comminuted structured steaks received higher, more desirable ($P<0.01$) tenderness ratings than intact muscle steaks (Table 10). Consumer evaluation results indicated both RER and SRV were between slightly tough and slightly tender. Within the comminuted structured steaks, consumer panelists rated Alg/Ca steaks slightly more ($P=0.07$) tender than $NaCl/PO_4$ structured steaks. Previous comparisons of $NaCl/PO_4$ steaks and Alg/Ca steaks (Means and Schmidt, 1986; Means et al., 1987) did not evaluate tenderness directly but did indicate there was no difference ($P>0.05$) in cooked bind of the two steak types when evaluated by experienced panelists.

Consumer panel flavor ratings were different between the types of steaks produced (Table 10). Intact muscle steaks received higher, more desirable ($P<0.05$) flavor scores than the comminuted structured steaks, with no difference ($P>0.05$) detected between RER and SRV or $NaCl/PO_4$ and Alg/Ca steaks. Results of previous laboratory studies evaluating the flavor of structured steaks produced by the algin/calcium binder have indicated off-flavors may exist due to unreacted Na-alginate (Means and Schmidt, 1986; Means et al., 1987).

Conclusions

The consumer acceptance of all four types of steaks suggested there are fabrication and merchandising alternatives available for the lean tissue within the beef forequarter. Although intact muscle steaks received higher ratings in the uncooked state than comminuted structured steaks, sensory evaluations indicated no unanimous preference for one type of steak over another. Thereby, the enhancement of fresh beef consumption, excluding ground beef, could be feasible if all types of steaks were made available to the consuming public. The production of structured meat products which can be marketed in a raw, refrigerated state, whether solid-muscle or comminuted, would improve the visibility of value-added products and increase purchasing alternatives for the consumer.

LITERATURE CITED

Addis, P.B. and Schanus, E.S. 1979. Massaging and tumbling in the manufacture of meat products. Food Technol. 33(4): 36.

Allen, C.E. and Foegeding, E.A. 1981. Some lipid characteristics and interactions in muscle foods - a review. Food Technol. 35(5): 253.

AMSA. 1978. Guidelines for cookery and sensory evaluation of meat. American Meat Science Association, Chicago, IL.

Anonymous. 1984. "Alginates: Seaweed Extracts," CECA, Inc. St. Louis, MO.

AOAC. 1980. "Official Methods of Analysis," 13th ed. Association of Official Analytical Chemists, Washington, D.C.

Bielski, W. 1987. Private communication. Balchem Corp., Slate Hill, NY.

Booren, A.M., Jones, K.W., Mandigo, R.W., and Olson, D.G. 1979. Processing factors influencing binding of meat pieces into restructured, fresh beef steaks. Abstract Proc. 71st Annual Meeting of the Am. Soc. of Anim. Sci., Tucson, AZ.

Booren, A.M., Jones, K.W., Mandigo, R.W., and Olson, D.G. 1981a. Effects of blade tenderization, vacuum mixing, salt addition and mixing time on binding of meat pieces into sectioned and formed beef steaks. J. Food Sci. 46: 1678.

Booren, A.M., Mandigo, R.W., Olson, D.G., and Jones, K.W. 1981b. Effect of muscle type and mixing time on sectioned and formed beef steaks. J. Food Sci. 46: 1665.

Booren, A.M., Mandigo, R.W., Olson, D.G., and Jones, K.W. 1981c. Vacuum mixing influences on characteristics of sectioned and formed beef steak. J. Food Sci. 46: 1673.

Booren, A.M., Mandigo, R.W., Olson, D.G., and Jones, K.W. 1982. Characterization of exudate proteins involved in binding meat pieces into sectioned and formed beef steak. J. Food Sci. 47: 1943.

Breidenstein, B.C. 1982. Intermediate value beef products (Restructured beef products). National Live Stock and Meat Board. Chicago, IL.

Breidenstein, B.C. and Williams, J.C. 1986. Red meat: Nutrient composition and actual consumption. National Live Stock and Meat Board, Chicago, IL.

Burke Marketing Research. 1987. Consumer climate for meat - executive summary. Prepared for the National Live Stock and Meat Board and The American Meat Institute.

Catsimpoolas, N. and Meyer, E.W. 1970. Gelation phenomena of soybean globulins. 1. Protein-protein interactions. Cereal Chem. 47: 559.

Chastain, M.F., Huffman, D.L., Hseih, W.H., and Cordray, J.C. 1982. Antioxidants in restructured beef/pork steaks. J. Food Sci. 47: 1779.

Choi, Y.I., Guenther, J.J., Busboom, J.R., May, S.G., Novotny, K.K., and Buchanan, D.S. 1987. Influence of USDA quality and yield grade on percent fat, Warner-Bratzler shear and cooking loss of chuck muscles. Anim. Sci. Res. Rep., Oklahoma Agr. Exp. Sta. MP-119: 50.

Cottrell, I.W. and Kovacs, P. 1980. Alginates. Ch. 2. In "Handbook of Water-Soluble Gums and Resins," R.L. Davidson (Ed.). McGraw-Hill Book Company, New York, NY.

CRC. 1972. Physical constants of inorganic compounds. In "Handbook of Chemistry and Physics," R.C. Weast (Ed.). The Chemical Rubber Co., Cleveland, OH.

Dalton, L.M. 1979. The effects of mechanical mixing time and salt on the chemical, physical and organoleptic properties of sectioned and formed fresh pork chops. M.S. thesis, Univ. of Nebraska, Lincoln.

Earle, R.D. 1968. Meat and fish coatings: Alginate coatings. In Pintauro, N. 1973. "Edible Coatings and Soluble Packaging," p. 188. Noyes Data Corp., Park Ridge, NJ.

Ferri, J.D. 1948. Protein gels. Adv. Prot. Chem. 4:1.

Glicksman, M. 1982. Functional properties of hydrocolloids. Ch. 3. In "Food Hydrocolloids," Vol. I. M. Glicksman (Ed.). CRC Press, Inc., Boca Raton, FL.

Huffman, D.L. 1980. Processing effects on fresh and frozen meat color. Proc. Recip. Meat Conf. 33: 4.

Huffman, D.L. and Cordray, J.C. 1979. Restructured fresh meat cuts from chilled and hot processed pork. J. Food Sci. 44: 1564.

Huffman, D.L. and Cordray, J.C. 1982. Processing systems - particle reduction systems (grinding, flaking, chunking, slicing). In "Proc. Int. Symp. Meat Science and Technology," p. 229. National Live Stock and Meat Board. Chicago, IL.

IFT Expert Panel on Food Safety and Nutrition. 1980. Dietary salt. A scientific status summary. Food Technol. 34(1): 85.

Johnson, R.C., Chen, C.M., Muller, T.S., Costello, W.J., Romans, J.R., and Jones, K.W. 1988a. Characterization of the muscles within the beef forequarter. J. Food Sci. (Submitted).

Johnson, R.C., Muller, T.S., Romans, J.R., Costello, W.J., and Jones, K.W. 1988b. Effects of algin/calcium and adipic acid concentrations on muscle-juncture formation. J. Food Sci. (Submitted).

Kinsella, J.E. 1976. Functional properties of proteins in foods: A survey. Crit. Rev. Food Technol. 7: 219.

Love, J.D. 1983. The role of heme iron in the oxidation of lipids in red meats. Food Technol. 37(7):117.

Macfarlane, J.J., Schmidt, G.R., and Turner, R.H. 1977. Binding of meat pieces: A comparison of myosin, actomyosin and sarcoplasmic proteins as binding agents. J. Food Sci. 42: 1603.

Mandigo, R.W. 1982. Overview of restructuring. In "Proc. Int. Symp. Meat Science and Technology," p. 223. National Live Stock and Meat Board. Chicago, IL.

McDowell, R.H. 1966. Alginates and their derivatives. In "The Chemistry and Rheology of Water Soluble Gums and Colloids," Society of Chemical Industry, London, England. Gordon and Breach, Science Publishers, Inc., New York, NY.

McDowell, R.H. 1977. "Properties of Alginates," 4th ed. Alginate Industries Limited, London, England.

McKeith, F.K., Devol, D.L., Miles, R.S., Bechtel, P.J., and Carr, T.R. 1985. Chemical and sensory properties of thirteen major beef muscles. J. Food Sci. 50: 869.

Means, W.J. 1985. Algin/calcium gel in structured meat products. Ph.D. Dissertation, Colorado State Univ., Fort Collins.

Means, W.J., Clarke, A.D., Sofos, J.N., and Schmidt, G.R. 1987. Binding, sensory and storage properties of algin/calcium structured beef steaks. J. Food Sci. 52: 252.

Means, W.J. and Schmidt, G.R. 1986. Algin/calcium gel as a raw and cooked binder in structured beef steaks. J. Food Sci. 51: 60.

Morris, E.R., Rees, D.A., and Robinson, G. 1980. Cation-specific aggregation of carrageenan helices: domain model of polymer gel structure. J. Mol. Biol. 138: 349.

Morris, E.R., Rees, D.A., Thom, D., and Welsh, E.J. 1977. Conformation and intermolecular interactions of carbohydrate chains. J. Supramol. Struct. 6: 259.

NAMP. 1980. "The Meat Buyer's Guide," The National Association of Meat Purveyors, Washington, D.C.

Neter, J. and Wasserman, W. 1974. "Applied Linear Statistical Models," Richard D. Irwin, Inc., Homewood, IL.

NLS & MB. 1979. Beef steak color guide. National Live Stock and Meat Board. Chicago, IL.

Ockerman, H.W. and Organisciak, C.S. 1979. Quality of restructured beef steaks after refrigerated and frozen storage. J. Food Prot. 42: 126.

Paterson, B.C. and Parrish, F.C., Jr. 1986. A sensory panel and chemical analysis of certain beef chuck muscles. J. Food Sci. 51: 876.

Pearson, A.M. and Wolzak, A.M. 1982. Salt - its use in animal products - a human health dilemma. J. Anim. Sci. 54: 1263.

Rees, D.A. and Welsh, E.J. 1977. Secondary and tertiary structure of polysaccharides in solutions and gels. Angew. Chem. Int. Ed. Encl. 16: 214.

Romans, J.R., Jones, K.W., Costello, W.J., Carlson, C.W., and Ziegler, P.T. 1985. "The Meat We Eat," The Interstate Printers & Publishers, Inc., Danville, IL.

Samejima, K., Hashimoto, Y., Yasui, T., and Fukazawa, T. 1969. Heat gelling properties of myosin, actin, actomyosin and myosin-subunits in a saline model system. J. Food Sci. 34: 242.

Sand, R.E. 1982. Nomenclature and structure of carbohydrate hydrocolloids. Ch. 2. In "Food Hydrocolloids," Vol. I. M. Glicksman (Ed.). CRC Press, Inc., Boca Raton, FL.

Sanderson, G.R. 1981. Polysaccharides in foods. Food Technol. 35(7): 150.

SAS Institute, Inc. 1985. "SAS User's Guide: Statistics," Version 5 ed. SAS Institute, Inc., Cary, NC.

Savell, J.W., Cross, H.R., and Smith, G.C. 1986. Percentage ether extractable fat and moisture content of beef longissimus muscle as related to USDA marbling score. J. Food Sci. 51: 838.

Schmidt, G.R. 1978. Sectioned and formed meat. Proc. of the 31st Reciprocal Meats Conference. 31: 18.

Schmidt, G.R., Mawson, R.F., and Siegel, D.G. 1981. Functionality of a protein matrix in comminuted meat products. Food Technol. 35(5): 235.

Schmidt, G.R. and Means, W.J. 1986. Process for preparing algin/calcium gel structured meat products. U.S. Patent 4,603,054.

Schmidt, G.R. and Trout, G.R. 1984. The chemistry of meat binding. Ch. 12. In "Recent Advances in the Chemistry of Meat," Vol. 12. A.J. Bailey (Ed.). Royal Society of Chemistry, London.

Schwartz, W.C. and Mandigo, R.W. 1976. Effect of salt, sodium tripolyphosphate and storage on restructured pork. J. Food Sci. 41: 1976.

Seideman, S.C. 1982. Utilization of meat and non-meat replacements in restructured products. In "Proc. Int. Symp. Meat Science and Technology," p. 245. National Live Stock and Meat Board. Chicago, IL.

Seideman, S.C. and Durland, P.R. 1982. Restructured red meat products: A review. J. Food Quality 6: 81.

Siegel, D.G., Church, K.E., and Schmidt, G.R. 1979. Gel structure of nonmeat proteins as related to their ability to bind meat pieces. J. Food Sci. 44: 1276.

Siegel, D.G. and Schmidt, G.R. 1979a. Crude myosin fractions as binders. J. Food Sci. 44: 1129.

Siegel, D.G. and Schmidt, G.R. 1979b. Ionic, pH, and temperature effects on the binding ability of myosin. J. Food Sci. 44: 1686.

Smith, G.C., Culp, G.R., and Carpenter, Z.L. 1978. Postmortem aging of beef carcasses. J. Food Sci. 43: 823.

Sofos, J.N. 1983. Effects of reduced salt (NaCl) levels on the stability of frankfurters. J. Food Sci. 48: 1684.

Steele, R.G.D. and Torrie, J.H. 1980. "Principles and Procedures of Statistics," McGraw-Hill Book Co., New York.

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

Terrell, R.N., Crenwelge, C.H., Dutson, T.R., and Smith, G.C. 1982. A technique to measure binding properties of non-meat proteins in muscle-juncture formation. J. Food Sci. 47: 711.

Trout, G.R. and Schmidt, G.R. 1984. Effect of phosphate type and concentration, salt level and method of preparation on binding in restructured beef rolls. J. Food Sci. 49: 687.

United States Department of Agriculture/Food Safety and Inspection Service (USDA/FSIS). 1986. Binder consisting of sodium alginate, calcium carbonate, lactic acid and calcium lactate. Fed. Reg. 51(159): 29456.

U.S. Bureau of Census. 1980. "U.S. Census of Population: General Population Characteristics: South Dakota," United States Government. PC80-1-C43.

USDA. 1975. Official United States Standards for Grades of Carcass Beef. Agr. Marketing Service, United States Dept. of Agriculture, Washington, D.C.

Wanstedt, K.G., Seideman, S.C., Donnelly, L.S., and Quenzer, N.M. 1981. Sensory attributes of precooked, calcium alginate-coated pork patties. J. Food Prot. 44: 732.

Williams, S.K., Oblinger, J.L., and West, R.L. 1978. Evaluation of a calcium alginate film for use on beef cuts. J. Food Sci. 43: 292.

APPENDIX

Figure 1 - In-home consumer beef steak evaluation preliminary questionnaire

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PRELIMINARY QUESTIONNAIRE

Name _____ * Household Number _____
Address _____ * Delivery Date _____
Telephone _____ **********
Store _____ Contact Date _____

1. Are you the primary meat purchaser within your household?
   YES
   NO If not, who is? _____

2. How many times in the last two weeks has your household consumed fresh beef, excluding ground beef?
   a. 1 time
   b. 2 - 3 times
   c. 4 or more times
   d. Nonusers

3. Are you the primary cook in the household?
   YES
   NO If not, who is? _____

4. What is the most common method of cookery for steak items in your household?
   a. Broil (Indoor or Outdoor)
   b. Pan fry
   c. Microwave

5. To what degree of doneness are steaks generally prepared in your home?
   a. Very rare b. Rare
   c. Medium rare d. Medium
   e. Well done f. Very well done

6. Number of household members within each age group.
   a. < 5 _____ b. 5-15 _____
   b. 16-25 _____ d. 26-35 _____
   e. 36-45 _____ f. 46-55 _____
   g. 56-65 _____ h. > 65 _____

Figure 2 - In-home consumer beef steak evaluation general instructions delivered with the evaluation packet

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IN-HOME BEEF STEAK EVALUATION

Household Number _____

Your household is participating in an in-home evaluation of four types of beef steaks that is intended to assess preferences. The steaks your household are evaluating are from federally inspected beef carcasses and differ only in their method of processing.

These steaks are being provided to you at no financial obligation. However, by agreeing to participate in this study, you have agreed to the following conditions:

(A) Your household has accepted delivery of the steaks on (date) and will prepare and consume the steaks within two days of delivery.

(B) The primary meat purchaser within your household must complete the BLUE FORM prior to cooking the steaks.

(C) The primary cook within your household must complete the GREEN FORM while cooking the steaks.

(D) Each member of the household that is over 5 years old must complete a YELLOW form while eating the steaks.

(E) All completed evaluation forms must be returned in the preaddressed, postage paid envelope.

(F) The primary meat purchaser of the household must answer a series of follow-up questions by telephone within three weeks of the steak delivery.

If at anytime you have questions concerning any aspect of this project, please contact one of the following people:

Roger Johnson or Dr. John Romans
Telephone (605) 688-5165
Department of Animal & Range Sciences
South Dakota State University
Brookings, SD 57007

Figure 3 - In-home consumer beef steak evaluation form for the primary meat purchaser

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IN-HOME BEEF STEAK EVALUATION

Household Number _____

Instructions for the raw product evaluation (BLUE) form.

1. This form is to be completed by (Name of the Primary Meat Purchaser) prior to cooking the steaks.
2. Lay out the four packages on a well lit, flat surface and note the identification numbers before proceeding with your evaluation.
3. Indicate your Age and Sex and the Date you performed this evaluation.
4. For each sample package, record a score for each of the following traits using the numerical codes listed on the BLUE FORM:
   a. COLOR DESIRABILITY - your perception of the steak color.
   b. FAT CONTENT - the quantity of fat in each package.
   c. OVERALL DESIRABILITY - your overall perception of each of the packages.
5. For each sample package, record the percentage (0-100%) of the steak surface area which is not normal beef color.
   EXAMPLES
   a. 0% - No discoloration.
   b. 100% - Entire surface area is discolored.
6. On the diagrams provided indicate the major regions of discoloration for those samples that have more than 20% surface discoloration.
7. Please make any comments you might have on the back side of the BLUE FORM.

IN-HOME BEEF STEAK EVALUATION
BLUE FORM

Household Number _____

1. Complete the following:
   Age _____ Sex _____ Date _____

2. Numerical codes

COLOR SCORE		FAT CONTENT		OVERALL SCORE	
8	Like extremely	8	None	8	Like extremely
7	Like very much	7	Practically none	7	Like very much
6	Like moderately	6	Traces	6	Like moderately
5	Like slightly	5	Slight	5	Like slightly
4	Dislike slightly	4	Modest	4	Dislike slightly
3	Dislike moderately	3	Moderate	3	Dislike moderately
2	Dislike very much	2	Slightly abundant	2	Dislike very much
1	Dislike extremely	1	Abundant	1	Dislike extremely

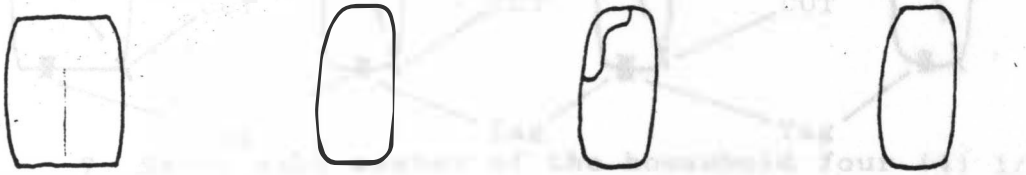
NOTE: Surface discoloration should be a percentage (0-100%) of the surface that is not normal beef color.

SAMPLE NUMBER	COLOR (1-8)	FAT CONTENT (1-8)	OVERALL (1-8)	SURFACE DISCOLORATION (0-100%)
(SRV)	___	___	___	_____
(Alg/Ca)	___	___	___	_____
(RER)	___	___	___	_____
(NaCl/PO_4)	___	___	___	_____

3. Major regions of surface discoloration.

SAMPLE NUMBER

(SRV) (Alg/Ca) (RER) (NaCl/PO_4)



4. Comments (on the back side).

Figure 4 - In-home consumer beef steak evaluation form for the primary cook

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IN-HOME BEEF STEAK EVALUATION

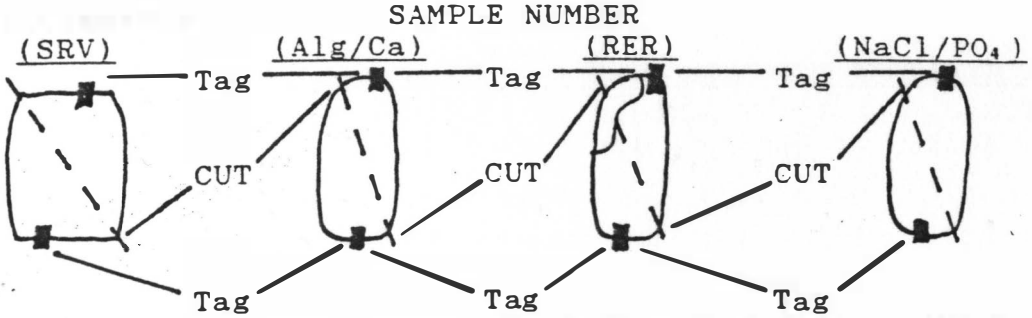
Household Number _____

Instructions for the cooking evaluation (GREEN) form.

1. This form is to be completed by (Name of the Primary Cook) following the cooking of the steaks.
2. Indicate your Age and Sex and the Date you performed this evaluation.
3. Note the identification tags attached to each steak. Leave the identification tags in each steak during the entire cooking and serving process.
4. Suggested cooking times for DESIRED DEGREES OF DONENESS.

DESIRED DEGREE OF DONENESS	SAMPLE NUMBER (SRV) FIRST SIDE	(SRV) SECOND SIDE	(Alg/Ca) FIRST SIDE	(Alg/Ca) SECOND SIDE	(RER) FIRST SIDE	(RER) SECOND SIDE	($NaCl/PO_4$) FIRST SIDE	($NaCl/PO_4$) SECOND SIDE
	minutes		minutes		minutes		minutes	
MEDIUM RARE	8 - 10		7 - 9		13 - 15		12 - 14	
MEDIUM	12 - 14		11 - 13		16 - 18		15 - 17	
WELL DONE	16 - 18		15 - 17		19 - 21		18 - 20	

5. Upon completion of cooking, record a SAMPLE INTEGRITY SCORE for each steak using the numerical code on the GREEN FORM.
6. Upon completion of cooking, subdivide each steak as shown in the following diagram with a sharp knife.



7. Serve each member of the household four (4) 1/2 portions of steak. Each 1/2 portion should have a different identification number.
8. Please make any comments you might have on the back side of the GREEN FORM.

IN-HOME BEEF STEAK EVALUATION
GREEN FORM

Household Number _____

1. Complete the following:
   Age _____ Sex _____ Date _____

COOKERY METHOD
(Circle the method used)

Broil (Indoor)

Broil (Outdoor)

Pan fry

2. Numerical codes

SAMPLE INTEGRITY SCORE

6	Intact
5	2 pieces
4	3 - 4 pieces
3	5 - 6 pieces
2	7 - 8 pieces
1	> 8 pieces

SAMPLE NUMBER	SAMPLE INTEGRITY (1-6)
(SRV)	___
(Alg/Ca)	___
(RER)	___
(NaCl/PO_4)	___

3. Comments.

Figure 5 - In-home consumer beef steak sensory evaluation form for household members over 5 years old

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IN-HOME BEEF STEAK EVALUATION

Household Number _____

Instructions for the sensory evaluation (YELLOW) form.

1. A YELLOW FORM is to be completed by every member of the household over 5 years old.
2. Indicate your Age and Sex and the Date you performed this evaluation.
3. Note the identification tags attached to each 1/2 steak portion. Each person should evaluate four (4) 1/2 steak portions, each with a different identification number.
4. For each steak sample, record a score for each of the following traits using the numerical codes listed on the YELLOW FORM:
   a. DEGREE OF DONENESS - evaluation of the internal color of the cut surface of the steak. Use the BEEF STEAK COLOR GUIDE as an aid.
   b. TENDERNESS
   c. JUICINESS
   d. FLAVOR
   e. OVERALL DESIRABILITY
5. Please make any comments you might have on the back side of the YELLOW FORM.

IN-HOME BEEF STEAK EVALUATION
YELLOW FORM

Household Number _____

1. Complete the following:
   Age _____ Sex _____ Date _____

2. Note the identification number attached to each steak portion.

3. Numerical codes

DEGREE OF DONENESS	SCORE		
6	Very rare	5	Rare
4	Medium rare	3	Medium
2	Well done	1	Very well done

TENDERNESS SCORE	JUICINESS SCORE	FLAVOR SCORE	OVERALL SCORE
8 Extremely tender	8 Extremely juicy	8 Like extremely	8 Like extremely
7 Very tender	7 Very juicy	7 Like very much	7 Like very much
6 Moderately tender	6 Moderately juicy	6 Like moderately	6 Like moderately
5 Slightly tender	5 Slightly juicy	5 Like slightly	5 Like slightly
4 Slightly tough	4 Slightly dry	4 Dislike slightly	4 Dislike slightly
3 Moderately tough	3 Moderately dry	3 Dislike moderately	3 Dislike moderately
2 Very tough	2 Very dry	2 Dislike very much	2 Dislike very much
1 Extremely tough	1 Extremely dry	1 Dislike extremely	1 Dislike extremely

SAMPLE NUMBER	DEGREE OF DONENESS (1-6)	TENDERNESS (1-8)	JUICINESS (1-8)	FLAVOR (1-8)	OVERALL (1-8)
(SRV)	___	___	___	___	___
(Alg/Ca)	___	___	___	___	___
(RER)	___	___	___	___	___
($NaCl/PO_4$)	___	___	___	___	___

4. Comments (on the back side).

Figure 6 - In-home consumer beef steak evaluation follow-up questionnaire

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FOLLOW-UP QUESTIOINNAIRE

Household Number _____ Delivery Date _____
Name of primary cook _____

1. How many years of schooling have you had?
   a. Less than 9 years
   b. 9 - 12 years
   c. More than 12 years

2. Occupation of the heads of the household.
   Male _____
   Female _____

3. What is the median household income?
   a. Less than $15,000 per year
   b. $15,000 - $39,999
   c. More than $40,000 per year

Table 1 - Chi-square analysis of raw steakette juncture success

Alg/Ca[a]	Unsuccessful raw junctures[b]	X^2 value, 1 df	
I	40		
		V, IV, III & II vs I	54.27**
II	27		
		V, IV & III vs II	27.15**
III	11		
		V & IV vs III	3.08
IV	6		
		V vs IV	1.03
V	1		

[a] Algin/Calcium level (%): I = 2.00/0.360, II = 2.25/0.405, III = 2.50/0.450, IV = 2.75/0.495 and V = 3.00/0.540.

[b] Possible junctures = 60.

**P<0.01.

Table 2 - Least-squares analysis of variance for successful raw juncture binding strength

Source	df	SS[a]	F	Prob.
Rep (R)	4	12778.8	1.18	0.3572
Algin/Calcium (AC)	4	114193.0	9.52	0.0005
R x AC	15	44997.6	1.45	0.1589
Adipic acid (AD)	2	1100.2	0.27	0.7719
R x AD	8	16452.1	1.12	0.3772
AC x AD	8	66881.1	1.99	0.0956
R x AC x AD	22	92215.1	2.57	0.0025
Steak(Rep)	15	40442.6	1.65	0.0909
AC x Steak(Rep)	51	105197.5	1.26	0.1997
AD x Steak(Rep)	30	54999.9	1.12	0.3490
Residual	54	88230.1		
Total	213			

[a] SAS GLM Type III sum of squares.

Table 3 - Chi-square analysis of cooked steakette juncture success

Alg/Ca[a]	Unsuccessful cooked junctures[b]	X^2 value, 1 df	
I	53		
		V, IV, III & II vs I	40.38**
II	47		
		V, IV & III vs II	41.13**
III	31		
		V & IV vs III	16.06**
IV	14		
		V vs IV	0.53
V	4		

[a]Algin/Calcium level (%): I = 2.00/0.360, II = 2.25/0.405, III = 2.50/0.450, IV = 2.75/0.495 and V = 3.00/0.540.
[b]Possible junctures = 60.
**P<0.01.

Table 4 - Least-squares analysis of variance for successful cooked juncture binding strength

Source	df	SS[a]	F	Prob.
Rep (R)	4	105436.5	14.45	0.0001
Algin/Calcium (AC)	4	51415.4	3.26	0.0539
R x AC	11	43322.1	1.19	0.3356
Adipic acid (AD)	2	10773.5	0.81	0.4796
R x AD	8	53421.7	1.44	0.2246
AC x AD	7	14225.8	0.34	0.9185
R x AC x AD	11	65696.6	1.25	0.3317
Steak(Rep)	15	27355.7	0.38	0.9651
AC x Steak(Rep)	30	99375.9	0.69	0.8110
AD x Steak(Rep)	27	124999.8	0.97	0.5417
Residual	16	76323.8		
Total	142			

[a]SAS GLM Type III sum of squares.

Table 5 - Least-squares analysis of variance for raw and cooked steakette gel thickness

Source	df	SS[a]	F	Prob.
Rep (R)	4	139.5	9.26	0.0001
Algin/Calcium (AC)	4	32.6	0.72	0.5909
R x AC	16	181.0	3.64	0.0001
Adipic acid (AD)	2	1.6	0.12	0.8924
R x AD	8	55.5	2.46	0.0209
AC x AD	8	33.0	0.43	0.8955
R x AC x AD	32	308.9	3.61	0.0001
Steak(Rep)	35	131.8	1.41	0.0731
AC x Steak(Rep)	138	428.4	1.16	0.1572
AD x Steak(Rep)	70	197.6	1.05	0.3766
Residual	248	663.9		
Total	565			

[a] SAS GLM Type III sum of squares.

Table 6 - Least-squares analysis of variance for cooked steakette yield

Source	df	SS[a]	F	Prob.
Rep (R)	4	2802.2	37.43	0.0001
Algin/Calcium (AC)	4	113.1	0.67	0.6227
R x AC	16	675.9	3.31	0.0004
Adipic acid (AD)	2	163.6	3.80	0.0692
R x AD	8	172.3	2.12	0.0651
AC x AD	8	642.5	1.14	0.3616
R x AC x AD	32	2245.0	9.34	0.0001
Steak(Rep)	15	280.7	2.49	0.0032
AC x Steak(Rep)	60	765.7	1.70	0.0072
AD x Steak(Rep)	30	304.7	1.35	0.1294
Residual	120	901.4		
Total	299			

[a] SAS GLM Type III sum of squares.

Table 7 - Least-squares analysis of variance for cooked steakette pH

Source	df	SS[a]	F	Prob.
Rep (R)	4	4.33	262.23	0.0001
Algin/Calcium (AC)	4	0.19	0.99	0.4405
R x AC	16	0.78	11.81	0.0001
Adipic acid (AD)	2	0.58	2.60	0.1349
R x AD	8	0.89	27.12	0.0001
AC x AD	8	0.60	1.12	0.3786
R x AC x AD	32	2.16	16.34	0.0001
Steak(Rep)	12	0.03	0.69	0.7643
Part(Steak)	8	1.29	38.98	0.0001
Part 1 vs Part 3	1	0.00	0.28	0.5988
Parts 1 & 3 vs Part 2	1	0.27	64.38	0.0001
AC x Part(Steak)	44	0.17	0.96	0.5478
Residual	755	3.12		
Total	896			

[a] SAS GLM Type III sum of squares.

Table 8 - Least-squares analysis of variance for in-home steak study proximate analysis - moisture

Source	df	SS[a]	F	Prob.
Rep (R)	9	103.62	8.11	0.0015
Treatment (T)	3	23.13	2.06	0.1285
Intact vs Comminuted	1	0.38	0.10	0.7517
RER vs SRV	1	0.29	0.08	0.7821
$NaCl/PO_4$ vs Alg/Ca	1	22.46	6.01	0.0210
R x T	27	100.87	3.78	0.0003
Steak(Rep)	10	14.20	1.44	0.2117
Residual	30	29.62		
Total	79			

[a] SAS GLM Type III sum of squares.

Table 9 - Least-squares analysis of variance for in-home steak study proximate analysis - fat

Source	df	SS[a]	F	Prob.
Rep (R)	9	60.04	2.51	0.0841
Treatment (T)	3	87.93	6.10	0.0026
Intact vs Comminuted	1	21.36	4.44	0.0445
RER vs SRV	1	59.83	12.45	0.0015
$NaCl/PO_4$ vs Alg/Ca	1	6.75	1.40	0.2464
R x T	27	129.79	2.23	0.0172
Steak(Rep)	10	26.59	1.23	0.3098
Residual	30	64.61		
Total	79			

[a] SAS GLM Type III sum of squares.

Table 10 - Least-squares analysis of variance for in-home steak study proximate analysis - protein

Source	df	SS[a]	F	Prob.
Rep (R)	9	19.21	2.33	0.1014
Treatment (T)	3	48.72	13.85	0.0001
Intact vs Comminuted	1	1.21	1.03	0.3190
RER vs SRV	1	43.98	37.51	0.0001
$NaCl/PO_4$ vs Alg/Ca	1	3.53	3.01	0.0939
R x T	27	31.65	2.04	0.0298
Steak(Rep)	10	9.14	1.59	0.1571
Residual	30	17.23		
Total	79			

[a] SAS GLM Type III sum of squares.

Table 11 - Least-squares analysis of variance for in-home steak study laboratory cooking loss

Source	df	SS[a]	F	Prob.
Rep (R)	9	147.0	1.76	0.1949
Treatment (T)	3	499.2	17.64	0.0001
Intact vs Comminuted	1	190.1	20.15	0.0001
RER vs SRV	1	54.0	5.72	0.0240
$NaCl/PO_4$ vs Alg/Ca	1	25.3	2.69	0.1128
R x T	27	254.7	3.51	0.0006
Steak(Rep)	10	92.6	3.45	0.0044
Degree of Doneness	1	16.6	6.20	0.0188
Residual	29	77.9		
Total	79			

[a] SAS GLM Type III sum of squares.

Table 12 - Least-squares analysis of variance for in-home steak study Warner-Bratzler shear evaluation

Source	df	SS[a]	F	Prob.
Rep (R)	9	95.1	2.90	0.0562
Treatment (T)	3	167.4	14.34	0.0001
Intact vs Comminuted	1	132.4	34.03	0.0001
RER vs SRV	1	15.7	4.03	0.0549
$NaCl/PO_4$ vs Alg/Ca	1	5.3	1.37	0.2528
R x T	27	105.0	1.24	0.1907
Steak(Rep)	10	36.4	1.16	0.3151
Degree of Doneness	1	1.1	0.37	0.5454
Residual	429	1344.4		
Total	479			

[a] SAS GLM Type III sum of squares.

Table 13 - Least-squares analysis of variance for in-home steak study TBA evaluation

Source	df	SS[a]	F	Prob.
Rep (R)	9	0.7108	24.19	0.0001
Day (D)	2	0.4553	6.68	0.0068
R x D	18	0.6136	20.23	0.0001
Treatment (T)	3	0.2440	8.25	0.0005
Intact vs Comminuted	1	0.0744	7.55	0.0106
RER vs SRV	1	0.0802	8.13	0.0082
$NaCl/PO_4$ vs Alg/Ca	1	0.0955	9.68	0.0044
R x T	27	0.2662	3.09	0.0016
D x T	6	0.0910	1.12	0.3623
R x D x T	54	0.7306	4.09	0.0001
Steak(Rep)	10	0.0327	0.99	0.4666
D x Steak(Rep)	18	0.0303	0.51	0.9417
T x Steak(Rep)	30	0.0958	0.96	0.5325
Residual	52	0.1721		
Total	229			

[a] SAS GLM Type III sum of squares.

Table 14 - Least-squares analysis of variance for in-home steak study TBA evaluation - Day 1

Source	df	SS[a]	F	Prob.
Rep (R)	9	0.3574	24.76	0.0001
Treatment (T)	3	0.1053	5.99	0.0029
Intact vs Comminuted	1	0.0202	3.44	0.0745
RER vs SRV	1	0.0032	0.55	0.4634
$NaCl/PO_4$ vs Alg/Ca	1	0.0819	13.99	0.0009
R x T	27	0.1581	2.57	0.0050
Steak(Rep)	10	0.0160	0.73	0.6888
Residual	30	0.0657		
Total	79			

[a] SAS GLM Type III sum of squares.

Table 15 - Least-squares analysis of variance for in-home steak study TBA evaluation - Day 33

Source	df	SS[a]	F	Prob.
Rep (R)	9	0.2204	19.01	0.0001
Treatment (T)	3	0.1070	16.14	0.0001
Intact vs Comminuted	1	0.0208	9.42	0.0049
RER vs SRV	1	0.0096	4.35	0.0466
$NaCl/PO_4$ vs Alg/Ca	1	0.0766	34.66	0.0001
R x T	27	0.0596	1.67	0.0877
Steak(Rep)	10	0.0129	0.97	0.4867
Residual	30	0.0398		
Total	79			

[a] SAS GLM Type III sum of squares.

Table 16 - Least-squares analysis of variance for in-home steak study TBA evaluation - Day 70

Source	df	SS[a]	F	Prob.
Rep (R)	9	0.7462	17.22	0.0003
Treatment (T)	3	0.1258	1.45	0.2504
Intact vs Comminuted	1	0.0353	1.22	0.2793
RER vs SRV	1	0.0983	3.40	0.0762
$NaCl/PO_4$ vs Alg/Ca	1	0.0000	0.00	0.9598
R x T	27	0.7809	3.92	0.0009
Steak(Rep)	8	0.0385	0.65	0.7264
Residual	22	0.1624		
Total	69			

[a] SAS GLM Type III sum of squares.

Table 17 - Least-squares analysis of variance for in-home steak study uncooked steak evaluation - color

Source	df	SS[a]	F	Prob.
Rep (R)	9	43.39	2.83	0.0035
Treatment (T)	3	30.41	5.95	0.0006
Intact vs Comminuted	1	28.98	17.00	0.0001
RER vs SRV	1	1.13	0.66	0.4172
$NaCl/PO_4$ vs Alg/Ca	1	0.57	0.34	0.5631
Sex (S)	1	2.39	1.40	0.2371
T x S	3	0.98	0.19	0.9025
Age (A)	3	12.21	1.25	0.3214
R x A	17	55.15	1.90	0.0182
T x A	9	8.09	0.53	0.8540
S x A	3	0.56	0.11	0.9542
Residual	249	424.39		
Total	297			

[a] SAS GLM Type III sum of squares.

Table 18 - Least-squares analysis of variance for in-home steak study uncooked steak evaluation - perceived fat content

Source	df	SS[a]	F	Prob.
Rep (R)	9	62.83	3.78	0.0002
Treatment (T)	3	62.64	11.31	0.0001
Intact vs Comminuted	1	31.12	16.86	0.0001
RER vs SRV	1	29.57	16.02	0.0001
$NaCl/PO_4$ vs Alg/Ca	1	1.39	0.76	0.3856
Sex (S)	1	0.12	0.07	0.7988
T x S	3	1.63	0.29	0.8292
Age (A)	3	11.95	1.14	0.3596
R x A	17	59.17	1.89	0.0197
T x A	9	5.51	0.33	0.9640
S x A	3	12.65	2.28	0.0795
Residual	249	459.60		
Total	297			

[a] SAS GLM Type III sum of squares.

Table 19 - Least-squares analysis of variance for in-home steak study uncooked steak evaluation - overall

Source	df	SS[a]	F	Prob.
Rep (R)	9	30.63	1.70	0.0905
Treatment (T)	3	15.40	2.56	0.0557
Intact vs Comminuted	1	12.73	6.34	0.0124
RER vs SRV	1	2.74	1.37	0.2434
$NaCl/PO_4$ vs Alg/Ca	1	0.02	0.01	0.9294
Sex (S)	1	5.81	2.89	0.0902
T x S	3	0.22	0.04	0.9905
Age (A)	3	0.89	0.15	0.9255
R x A	17	32.64	0.96	0.5082
T x A	9	6.90	0.38	0.9432
S x A	3	6.37	1.06	0.3675
Residual	246	493.77		
Total	294			

[a] SAS GLM Type III sum of squares.

Table 20 - Least-squares analysis of variance for in-home steak study uncooked steak evaluation - surface discoloration

Source	df	SS[a]	F	Prob.
Rep (R)	9	12191.7	2.90	0.0028
Treatment (T)	3	3798.2	2.71	0.0458
Intact vs Comminuted	1	3538.1	7.57	0.0064
RER vs SRV	1	152.5	0.33	0.5672
$NaCl/PO_4$ vs Alg/Ca	1	161.6	0.35	0.5572
Sex (S)	1	200.3	0.43	0.5134
T x S	3	1347.2	0.96	0.4120
Age (A)	3	2369.0	1.39	0.2809
R x A	17	9680.8	1.22	0.2505
T x A	9	2077.0	0.49	0.8782
S x A	3	3068.6	2.19	0.0900
Residual	247	115485.4		
Total	295			

[a] SAS GLM Type III sum of squares.

Table 21 - Least-squares analysis of variance for in-home steak study sensory evaluation - tenderness

Source	df	SS[a]	F	Prob.
Rep (R)	9	20.17	1.00	0.4422
Treatment (T)	3	470.58	23.16	0.0001
Intact vs Comminuted	1	434.38	64.13	0.0001
RER vs SRV	1	9.51	1.40	0.2463
$NaCl/PO_4$ vs Alg/Ca	1	25.69	3.79	0.0619
R x T	27	182.88	3.01	0.0001
Sex (S)	1	1.20	0.53	0.4663
Age (A)	4	0.12	0.04	0.8493
R x A	9	27.69	1.37	0.1994
Degree of doneness	1	12.41	5.51	0.0191
Residual	807	1817.62		
Total	858			

[a]SAS GLM Type III sum of squares.

Table 22 - Least-squares analysis of variance for in-home steak study sensory evaluation - juiciness

Source	df	SS[a]	F	Prob.
Rep (R)	9	26.68	1.53	0.1319
Treatment (T)	3	10.18	1.53	0.2297
Intact vs Comminuted	1	4.55	2.05	0.1639
RER vs SRV	1	1.77	0.80	0.3793
$NaCl/PO_4$ vs Alg/Ca	1	3.94	1.78	0.1938
R x T	27	59.96	1.15	0.2755
Sex (S)	1	0.22	0.12	0.7342
Age (A)	1	1.41	0.55	0.4765
R x A	9	23.06	1.33	0.2196
Degree of doneness	1	42.60	22.03	0.0001
Residual	805	1556.68		
Total	856			

[a]SAS GLM Type III sum of squares.

Table 23 - Least-squares analysis of variance for in-home steak study sensory evaluation - flavor

Source	df	SS[a]	F	Prob.
Rep (R)	9	19.73	0.90	0.5270
Treatment (T)	3	34.05	2.03	0.1340
Intact vs Comminuted	1	31.98	5.71	0.0242
RER vs SRV	1	1.43	0.26	0.6175
$NaCl/PO_4$ vs Alg/Ca	1	0.66	0.12	0.7339
R x T	27	151.31	2.29	0.0002
Sex (S)	1	0.22	0.09	0.7651
Age (A)	1	1.41	0.58	0.4472
R x A	9	28.60	1.30	0.2326
Degree of doneness	1	0.60	0.25	0.6198
Residual	805	1966.86		
Total	856			

[a] SAS GLM Type III sum of squares.

Table 24 - Least-squares analysis of variance for in-home steak study sensory evaluation - overall

Source	df	SS[a]	F	Prob.
Rep (R)	9	28.64	1.30	0.2354
Treatment (T)	3	0.70	0.21	0.6595
Intact vs Comminuted	1	0.03	0.01	0.9295
RER vs SRV	1	0.01	0.00	0.9664
$NaCl/PO_4$ vs Alg/Ca	1	0.01	0.00	0.9626
R x T	27	116.72	1.76	0.0103
Sex (S)	1	1.41	0.57	0.4495
Age (A)	1	0.70	0.21	0.6595
R x A	9	30.22	1.37	0.1992
Degree of doneness	1	0.08	0.03	0.8601
Residual	806			
Total	857			

[a] SAS GLM Type III sum of squares.