THE RELATIONSHIP OF CERTAIN PHYSICAL AND CHEMICAL FACTORS TO COOKING AND SENSORY EVALUATIONS OF BEEF

by

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INTRODUCTION

To the meats researcher quality refers only to those carcass traits associated with sensory characteristics (Bray, 1963). In the broad sense, beef quality includes special features and distinctive traits that contribute toward consumer appeal.

Beef quality factors include physical as well as chemical characteristics measured by visual appraisal, mechanical measurements and chemical tests. Most quality indicators have been measured by subjective evaluations, as simple objective measurements have not yet been developed that will accurately measure the desired quality factor. A purely objective test is needed to measure or evaluate factors as flavor, aroma, tenderness, juiciness, texture and color. The correlation of objective tests to subjective observations would be helpful. A great deal of work has been done in relating specific characteristics of meat to ultimate consumer acceptability.

Much work has been done in evaluating the various quality factors. However, disagreement exists among research workers concerning the degree of importance to place on the various quality factors and their interrelationships. As meat is the foundation of the American diet and the consumer is conscious of sensory characteristics, quality research is very important. In this study, correlation coefficients have been calculated between various physical and chemical indicators of beef quality and cooking and sensory data. Several new approaches have been tried, including the determination of water holding capacity by three methods and an attempt to relate maturity to bone ossification by use of a penetrometer.

REVIEW OF LITERATURE

The Effect of Marbling on Beef Quality

Marbling has long been associated with and accepted as a measure of meat quality. It has been the basis of the U. S. grading standards since their introduction. In general, fatter (more marbled) beef is graded higher than less well marbled beef. The relationship of marbling to tenderness, juiciness and other eating qualities of beef has received much attention by research workers over the years. The results of much of this work has been conflicting.

Marbling can be defined as intramuscular fat that is visible to the eye. Intramuscular fat is any fatty tissue found between or around the muscle fibers and bundles within the structural unit of a muscle.

Ether extract is usually thought of as a measure of marbling. Cover et al. (1956) stated that ether extract measures not only fat seen as flecks of marbling, but, also fat deposits along seams of connective tissue. In addition, deposits of fat too small to be visible and ether soluble substances which are not true fats are also included.

Early studies were reported in the cooperative meat investigations. The U.S.D.A. reported (1928) a number of correlations between measurements of composition or quality using beef ribs. Correlations between marbling and age, grade, panel tenderness and Warner Shear values were 0.03 (±.05), 0.86 (±.08), 0.18 (±.05) and -.04 (±.04) respectively.

Fineness and amount of marbling were not related to palatability in a study of seven beef ribs of varying quality (U.S.D.A., 1930). Although no conclusions can be drawn from this study due to small numbers used, it was interesting to note their final statement. "These differences indicate the need for a continued effort to identify and control the factors of inheritance, feeding and management that create real consumer value in meat. It is probable that successful research along this line would finally make possible consistent production of the most desirable beef."

Nelson et al. (1930) indicated fatness was a factor in improving tenderness. Beef from feeder cattle was less tender than beef from similar cattle after fattening. Barbella et al. (1939) reported that higher juiciness scores were associated with fatter beef. There was also a highly significant effect of fatness on flavor.

Mackintosh and Hall (1936) correlated shear tenderness values to marbling scores determined by a grading chart. The relationship between tenderness (shear) and marbling was high (r = 0.650). They reported a correlation of 0.675 between marbling and tenderness measured with a taste panel.

Hankins and Ellis (1939) found no relationship between fatness and tenderness. A correlation of -.108 (±.082) was found between shear value and intramuscular fat. A total of 797 cattle and 924 lambs were included in this study. They concluded that variations in tenderness were caused by factors other than fatness.

Ramsbottom et al. (1945) compared 50 muscles from four beef animals. Variations in fat were determined. Tenderness did not correlate appreciably with ether extract values. They reported that a sample of most (88%) of the muscles of beef did not indicate a relationship between chemical fat and tenderness.

A significant but "poor" correlation (r = 0.47) was found between tenderness and intramuscular fat by Husaini et al. (1950A). Twenty carcasses were selected to represent various grades. A later paper

(1950B) reported no relationship between marbling and tenderness, but they concluded this was probably due to uniformity of feeding and management.

Gaddis et al. (1950) studied the fat content of press fluid from the rib eye of beef. No relationship was found between percent press fluid and scores for quality of juice. A direct curvilinear relationship was found between percent fat in press fluid and scores for quality and quantity of juice. Fat content of the meat was not significantly related to quantity of juice although a trend appeared.

Wang et al. (1954) reported it is not the total fat, but the manner in which the fat is distributed throughout the muscle that has an influence on tenderness. The "linear" fat content of raw beef correlated well with panel tenderness scores for cooked beef. "Linear" fat was determined quantitatively (histological sections) by measuring the largest axis of each fat island and expressing the sum of this value as the "linear" fat in a raw sample. The higher (length) the "linear" fat per sample the more tender the muscle after cooking.

Sex may also be related to marbling. Wierbicki et al. (1954) studied the effect of castration on the quality of beef. No relation was found between marbling and tenderness when steers and bulls were studied separately (aged 15 days). A relation ($r = 0.325$, $P < .01$) was found when all animals were considered. It was stated that marbling may be a sign of sex difference rather than tenderness. In a later report, (Wierbicki et al. 1956) no significant relation was found between tenderness and marbling in heifers, steers and bulls.

Cover et al. (1956) observed that fatness seemed more closely related to tenderness scores in bottom round than short loin strip steaks. Tenderness scores were more closely related to ether extract scores than other measures of fatness. Juiciness was more closely related to fatness than tenderness. She concluded that ether extract is somewhat associated with juiciness and tenderness of meat. Fatness accounted for about 10 percent of the variation in tenderness and 25 percent of the variation in juiciness in broiled loin steaks. In braised bottom round steaks the figures were 30 and 5 percent respectively.

In a study of 325 steers, Palmer et al. (1957) found a correlation of -.178 between shear force measurements and ether extract from the eye muscle. This relationship accounted for 3.2 percent of the total variation in shear tenderness measurements. Marbling was significantly related to panel and shear tenderness of the rib eye in a study of 536 carcasses of known feeding and management (Palmer et al. 1958). However, they did not state the correlation coefficient.

Further work by Cover et al. (1958) found carcasses with a higher percentage of ether extract and separable fat to be more tender. Individual groups within the report were irregular (some were related, others were not). The highest correlation between ether extract and shear value ($r = -0.330$) accounted for less than 11 percent of the total variation in shear value. Palmer et al. (1958) found marbling to account for 11 percent of the variance in panel tenderness.

Simone et al. (1958) found little evidence for a relationship between taste panel score and percent fat. Flavor was more closely related to marbling than total fat. Correlations of 0.319, 0.178 and 0.542 were found between percent intramuscular fat (rib eye) and tenderness, juiciness, and flavor. The correlations for top round were 0.314, 0.079 and 0.437 for the same factors. Both cuts were oven roasted.

Wellington and Stouffer (1959) studied 121 beef carcasses varying in grade from standard to prime. Marbling, as indicated by photographic standards, was compared to tenderness and juiciness. Marbling was not significantly related to shear values ($r = -0.080$). Panel tenderness showed a higher relationship to marbling, ($r = 0.263$) and accounted for about 7 percent of the variation in tenderness. Marbling and ether extract were significantly related to panel juiciness ($r = 0.188$ and 0.296).

Alsmeyer _et al_. (1959) found marbling to account for 6.9 percent of the variation in panel tenderness and 12.4 percent of the shear tenderness variation. Low, but significant, correlations were found for marbling scores versus tenderness. With age held constant, marbling versus tenderness scores gave a correlation of 0.26. Marbling influenced shear tenderness more strongly than age at the time of slaughter did.

Doty and Pierce (1961) studied beef muscle characteristics as related to grade and weight. Samples of _longissimus dorsi_ were taken at three locations and location was found to affect the amount of intramuscular fat. Samples of _semitendinosis_ were also taken. Aging tended to depress the effects of marbling on tenderness. Tenderness was highly related to marbling and intramuscular fat before aging, but this effect decreased after aging 2 weeks and was of little significance after 4 weeks of aging. This effect might be explained by the high number of carcasses from the higher grades. Marbling was related to juiciness, but intramuscular fat levels above 8 percent had little effect in terms of increased juiciness.

Kropf and Graf (1959A) in a study of 334 beef carcasses of varying weights and grades found marbling related to several factors. Correlations between marbling and sensory tenderness, and mechanical shear were 0.62 and 0.79 respectively. The relation to flavor and juiciness was

0.26 and 0.37. An interrelationship was found between subcutaneous fat, intramuscular fat and flavor (1958B). As fat levels increased, the desirability of flavor increased.

Cover and Hostetler (1960) found ether extract inconsistently related to tenderness. They theorized that marbling would have an important effect on tenderness for the following reasons: fat deposited in the cells may distend them and make them more tender; fat may also spread apart the strands of connective tissue between the muscle fibers and between the muscle bundles, making the meat more tender. This has not been proven, however.

Tuma et al. (1962) found marbling levels did not significantly influence the tenderness of longissimus dorsi, particularly in younger (18 month) cattle. Carcasses with "slightly abundant" marbling (42 and 90 months old at slaughter) were more tender than carcasses with "slight amount" of marbling.

Blumer (1963) in summarizing the reports of a number of workers, estimated the association of marbling and panel tenderness variance due to marbling. Prorated according to the number of samples represented among the studies, the average value would be about 5 percent. Mean correlation coefficients for marbling and intramuscular fat versus juiciness were quoted as 0.38 and 0.39 respectively.

A feeling exists that marbling should not be overlooked altogether in selecting quality meat. Wilson (1954) stated that when the association between tenderness and marbling breaks down, the technologist may still justify its need on the basis of firmer, juicier more appetizing cuts of meat.

Differences in results in many cases may be due to the specific design of the experiment. Relationships between physical, sensory and chemical characteristics must be determined in studies adequately representing the population studied to be of practical value.

The Relationship of Age of Animal to Beef Quality

The age at which cattle reach market has declined in the past decade. It is common for cattle less than two years old to be marketed today with the trend toward smaller cuts. With this change in age the interaction of various quality traits has also changed. The influence of age has been generally accepted to result in more tender meat from young animals and more flavorful meat from older animals. Age or maturity of the animal also plays an important role in the meat grading system.

Nelson *et al.* (1930) found no significant difference in tenderness of beef from calves, yearlings and two year olds. Juiciness was reported to increase with age but flavor was not influenced by age of animal. Cline *et al.* (1932) and Brady *et al.* (1937) reported that meat from cows was less tender than meat from heifers or steers.

Barbella *et al.* (1939) found greatest flavor differences between animals under 11 months and those older. No difference was noted in animals ranging in age from 12 to 30 months. Animals varied in breeding and management.

A trend in composition was noted by Hankins (1945). As age and weight increase, meat animals in general tended to have more fat, with decreasing proportions of water, protein and ash.

Hiner and Hankins (1950) studied the effect of animal age at time of slaughter on tenderness. Fifty-two animals were used which varied widely as to age. In summary, they stated that as animal age increased, tenderness decreased. Carcasses were aged 12 - 15 days at 33 - 35° F. Wierbicki <u>et al</u>. (1954) observed that age at slaughter contributes to tenderness. Sex seems to be less important than age. They concluded that tenderness is probably influenced more by age than any other single factor.

Jacobson and Fenton (1956A) found differences in quality factors of beef from Holstein heifers of 8, 12, 16, and 20 months of age. There was more marbling with increased age. The 8 and 12 month groups were ranked higher in all sensory factors than the 16 and 20 month groups. An increase (1956B) in color (redness) with increased age was also noted.

With increased age, carcass weight increased. Fat and nitrogen content of raw meat also increased (1956B). Shear value increased with age. The percentage weight and evaporation losses did not vary considerably with age.

Kropf and Graf (1959B) reported that lighter weight carcasses received higher acceptance ratings when compared to carcasses weighing 600 - 700 lbs. or 800 - 900 lbs. Highest ether extract content of the loin eye was found in the heavier carcasses. As the beef animal matured, a pronounced tendency existed for carcass lean muscle to become coarser in texture and darker colored (1959A).

Alsmeyer <u>et al</u>. (1959) in a study of Brahman and Shorthorn cattle found that slaughter age, with marbling held constant, had a greater influence on panel score tenderness than did marbling with age held constant. Age was related to tenderness without respect to degree of marbling. Age at slaughter accounted for 8.1 and 6.3 percent of the variability in tenderness by panel and shear.

Simone *et al.* (1959) studied the relationship of age (18 and 30 month old Hereford steers) to eating quality. Age was related to tenderness, favoring the younger animals. Juiciness and flavor were not significantly affected by age. The older and "choice" grade carcasses were darker and redder than the younger and "good" grade carcasses. Tenderness in both top round and rib roasts decreased with increased animal age (1958). Dunsing (1959) noted that consumer household panels favored steak from the younger carcasses consistently.

Tuma *et al.* (1962) compared the tenderness of 24 Hereford females representing 18, 42 and 90 months of age. Each carcass had or closely approached either a "slight amount" or a "slightly abundant" degree of marbling. Tenderness decreased significantly with increases in animal age with the greatest difference between 18 and 42 month old animals. The 42 and 90 month animals were similar in tenderness. The critical age was suggested to fall between 18 and 42 months. This agreed with the results of Dunsing (1959) and Simone *et al.* (1959). Moisture, ash, protein and fat did not differ significantly among age groups. Taste panel flavor and juiciness scores were not related significantly to age.

In a further report (1963) Tuma *et al.* reported that moisture was highest at 6 months (age). Panel and shear values indicated that 6 month old calves were less tender at 2 days post mortem than the 18 month olds. However, upon aging 14 days, 6 month olds were more tender. Flavor was not influenced by age. Six month cattle were just as desirable as the older groups. Tenderness of cuts from 18 month old cattle were affected only slightly by aging 14 days.

Henrickson (quoted by Palmer, 1963) obtained Warner-Bratzler shear data on 563 steers and females of similar breeding. Shear values indicated that longissimus dorsi muscle from 18 month old animals was more tender than the same from 6, 42 and 90 month old animals.

Palmer (1963) quoted a Florida study using 538 calves, steers, heifers, cows and bulls of known breeding and age. They represented various breeds and ranged from 5 to 99 months in age at slaughter. Grades ranged from "cutter" to "prime" and carcasses were not aged. Most correlations between age and tenderness, within specific marbling groups were not significant. Management was not the same for all groups. Sample correlations between age at slaughter and panel and shear tenderness were -.25 and -.27. Both were significant.

Maturity in beef is subjectively determined by standards established by the grading service. Bray (1963) stated that until we develop objective measurements of maturity in carcasses we cannot establish with reasonable accuracy the relative effect of maturity upon palatability in research animals or critically compare research results.

The Relationship of Grade to Beef Quality

Since current systems of grading are based on subjective observations, much research has been directed toward developing objective techniques for determining beef quality. The purpose of grading is to classify carcasses according to use and desirability. Marbling and maturity, the prime factors considered, are thought to be overemphasized by some workers.

Wanderstock and Miller (1948) reported grade differences with regard to flavor, tenderness and juiciness. Harrison et al. (1949) also found tenderness to be related to grade.

Husaini et al. (1950A) in a test using 20 animals found a correlation of 0.66 between carcass grade and tenderness by panel. This was to be expected, they explained, because the carcasses were selected in a packing house and the history unknown. In a later report (1950B) using cattle fed similar rations for 1 year prior to slaughter, no relationship was found. This was explained as being due to similar management and age.

Paul and Bratzler (1955) compared tenderness of the longissimus dorsi muscle from "prime," "good" and "commercial" beef animals. "Prime" was found to be most tender. Increasing cold storage time or aging tended to minimize the difference.

Griswold (1955) found a greater difference in animals within a grade than between grades with regard to tenderness. Higher palatability scores were obtained for "prime" than "commercial" when top and bottom round steaks were braised.

Wierbicki et al. (1955) reported that carcass grade was closely related to tenderness in samples of 3 days post mortem, but less closely related at 15 days post mortem.

Cover et al. (1958) concluded that carcass grades for beef under the present standards are not satisfactory indicators of tenderness. The study involved 203 carcasses ranging from "cutter" to "prime." When the tenderness ratings (panel and shear) were plotted against carcass grade a wide scattering in ratings were found for different animals within a grade. Some of the lower grading carcasses had tenderness scores as high as some of the higher grading carcasses.

Alsmeyer et al. (1959) found significant correlations between federal grades and tenderness. Since marbling and age are the chief factors considered in grading, multiple correlations between tenderness scores and marbling and age could be compared to simple correlations between tenderness and grade. Among Shorthorn progeny a multiple correlation coefficient of 0.39 was obtained, whereas, the simple correlation between carcass grade and panel tenderness was -0.28. This difference in sign (±) is meaningless since a multiple correlation does not possess a sign. Carcass grade accounted for 11.5 and 20.2 percent of the variation in tenderness by panel and shear.

Simone et al. (1959) also found grade to be related to tenderness. Taste panels scored "choice" grade cuts higher in tenderness, juiciness, and flavor as compared to those from "good" grade carcasses indicating a grade relationship. Top round and rib roasts from 18 and 20 month old steers were used in the study.

Kropf and Graf (1959A) studied 334 carcasses of varying grade and class. Higher graded steaks were more tender by both shear and panel scores. Juiciness and flavor were not significantly affected by either grade, class or weight. They concluded that U.S.D.A. grades do a good job in differentiating between various tenderness levels. Higher ether extract, lower shear values and higher panel scores were paralleled by increasing grade. In a later report (1959B) they found carcasses with thicker fat covering and firmer lean tended to produce more tender cuts.

Grade was significantly related to marbling, ether extract, panel tenderness, shear value and rib eye area in a study of "short loin" steaks from 536 beef carcasses of known feeding and management (Palmer 1958). Grade accounted for about 8 percent of the variability in panel tenderness.

Cover et al. (1960) obtained tenderness data from cooking bottom round and top loin steaks by four methods. Carcass grade was not consistently nor closely related to tenderness. Connective tissue in the meat (scored by taste panel) was not noticeably more tender in higher grading carcasses. The relationship between tenderness (shear and panel) and grade was variable depending on the method of cooking. She stated that factors other than those considered in grading are involved in tenderness.

Shaw (1957) stated that "prime" and "choice" carcasses may be initially less tender than "standard" carcasses of similar maturity. However, "prime" and "choice" carcasses may be tenderized by aging to a far greater degree than "standard."

Doty and Pierce (1961) made an extensive study of beef muscle characteristics as related to grade. Marbling and fatness increased with grade. Juiciness increased with weight within a grade and between grades, however, it was not consistently related to any other factor except fat content. Rib eye from "prime" as compared to "commercial" and "good" had a lower shear value (raw and cooked), more press fluid (raw), less nitrogen (cooked), more marbling and brighter color. In addition, "prime" had a higher flavor score.

Color and its Relationship to Beef Quality

Color of meat is not necessarily a guide to eating quality. It has psychological and commercial significance and is usually thought to be associated with freshness and wholesomeness as well as animal age by the consumer.

Color can be measured both subjectively and objectively. Measurements on light reflected from the meat surface or comparison of the surface color to known standards are the most common methods.

Myoglobin is the pigment primarily responsible for meat color. It undergoes a number of reactions, depending on the conditions of the meat, to form the characteristic meat colors. Myoglobin is a complex protein containing a non-peptide portion as well as a peptide portion. Its function is the storage of oxygen for muscle cells.

The non-peptide portion is called heme and is composed of two parts: an iron atom and a large planar ring, the porphyrin. The protein portion is known specifically as globin. (American Meat Institute Foundation. 1960 p. 88)

Color can be influenced by age, heredity, treatments before and after slaughter, concentration of myoglobin and condition of the muscle. A number of workers have studied color and its relationship to eating qualities.

The relationship of color to tenderness was studied by Husaini (1950B). Muscle color showed no relationship to beef tenderness at 3 days post-mortem, but a significant relationship was observed at 15 days. Results were interpreted as indicating the importance of muscle plasma, as represented by muscle hemoglobin, in the tenderness of beef. Wierbicki _et al_. (1954) reported color is not associated with tenderness except as it may indicate age or sex. Tuma (1963, 1962) found little relationship between color versus tenderness and other quality indicators.

Kropf and Graf (1959A) found a significant relationship between subjective lean color and shear value ($r = -.74$). Color was also related to marbling and texture and firmness of lean. The relationship to tenderness may have been due to the relationship of color to these other factors. According to Doty and Pierce (1961) color of rib eye was significantly related to tenderness of fresh samples. There was a trend for the same relationship with aged samples. Color was also related to grade as "prime" had a lighter color than "good" or "commercial." Bright lean color is generally accepted as a desirable characteristic.

Many workers have found color to be influenced by age. It is generally accepted that color becomes darker with age according to Wanderstock and Miller (1948), Jacobson and Fenton (1956), Simone et al. (1959), Dunsing (1959), Kropf and Graf (1959) and Tuma (1962, 1963).

An increase in redness was noted by Jacobson and Fenton (1956) as the plane of nutrition is increased. Rations meeting 60, 100 and 160 percent of a recommended basal requirements were fed to Holstein bulls and heifers. Loin steaks from the 160 percent ration were more tender than the 60 percent group. Wanderstock and Miller (1948) found little effect on color due to feed and grade differences.

Tuma et al. (1963, 1962) measured color of longissimus dorsi steaks with a photovolt reflectance meter. The steaks were darker with advancing age and became lighter and brighter after aging 14 days. Similar results were obtained by Doty and Pierce (1961).

Darker color beef due to advancing age cannot be compared to that of "Dark Cutting" beef. Beef that cuts red to purplish black and does not brighten up on exposure to air is termed "Dark Cutting Beef." It has been shown by Hall et al. (1944), Lawrie et al. (1948) and Hedrick et al. (1959) that dark cutting beef is characterized by an abnormally high pH, low glucose, practically no glycogen, high inorganic phosphate, low oxidation potential and rapid oxygen uptake. The cause of dark cutting beef has been reported as due to prolonged ante-mortem stress. No significant differences in eating qualities were detected between dark and bright beef from animals of the same approximate age and degree of finish (Hedrick et al. 1959).

The Relationship of Muscle pH to Beef Quality

Little relationship has been found by most workers between muscle pH and other quality characteristics.

Wanderstock and Miller (1948) found little change in pH due to method of feeding or grade. Doty and Pierce (1961) found no relationship to grade and weight. Husaini (1950A, B) found no indication of pH being related to tenderness. Hedrick et al. (1959) found no relationship between pH and cooking data and sensory evaluations. No significant differences could be detected between dark and bright beef if the dark color is due to high pH caused by glycogen depletion. Cooking causes a slight but definite rise in pH according to Doty and Pierce (1961). Tuma et al. (1963) reported a lower pH with increasing age. It ranged from 5.91 at 6 months of age to 5.26 at 90 months. Aging is generally accompanied by a rise in pH (Doty and Pierce, 1961; Tuma et al. 1963).

Color has been shown to be related to pH. A positive relationship between dark cutting beef and high muscle pH was reported by Hall et al. (1944) and Hedrick et al. (1959). Winkler (1939) reported a darkening in color with the rise in muscle pH. Doty and Pierce (1961) also indicated this trend. Wanderstock and Miller (1948) found no relationship between pH and color.

Objective Measures for Predicting Quality

Because of individual subjective differences in judging eating qualities, objective measures have been developed as a more precise and reproducable procedure. No satisfactory device has been developed that will predict eating qualities of raw meat. Reviews have been written regarding objective tenderness measurements by Schultz (1957) and Pearson (1963).

Tenderness. Numerous devices have been developed for measuring tenderness. Most of these have been shearing devices, including the Lehman device, Warner-Bratzler shear, Child-Satorius shear, Christel texturemeter, slice tenderness evaluator and the Kramer shear. Other devices, such as, the penetrometer have been used to measure penetration. Devices have even been made to approximate chewing motion and effort. Work, as measured by the amount of electricity used in grinding a meat sample is another approach. In addition, various pressing methods have been used. Of these, the Kramer and the Warner-Bratzler shears afford the best relationship to sensory means of measuring tenderness. Correlations of the Warner-Bratzler shear versus sensory methods are in the neighborhood of 0.60 to 0.85 (Pearson, 1963). This is a fairly good estimate considering the variability of taste panels alone.

Juiciness. Juiciness has also been determined objectively with a mechanical device. However, results have not been as favorable as with tenderness. A method for studying juiciness was developed by Child and Baldelli (1934) at Minnesota. The Carver Press has been used by many workers. Tannor et al. (1943) found a correlation coefficient of 0.92 between volume of press fluid and panel juiciness. Satorius and Child (1938) found no difference between press fluid from "medium" and "good" grade heifers. Wanderstock and Miller (1948) and Gaddis et al. (1950) found meat with higher fat content lower in total press fluid. Therefore, beef having a higher degree of finish, and a lesser amount of press fluid should be juicier when cooked. Doty and Pierce (1961) found juiciness scores were not related to press fluid quantity.

Under well controlled conditions, the press fluid content of meat may give some indication of juiciness. However, most workers have indicated a trained panel will in most cases give more reliable results. Press fluid may be more valuable in its relationship to other quality factors.

Firmness. The penetrometer has been used as a measure of tenderness and firmness by several workers. Hiner et al. (1941) found a good relationship between penetrometer scores (round point) and subjective scores for firmness of pork fat. Pilkington (1960) found penetrometer readings (single bull and multiple spike) related to panel firmness evaluations in beef muscle. Pearson (1963) stated that penetrometer readings have not been closely related to meat tenderness. Penetrometer force and actual tenderness apparently are quite different. This is supported by the work of Doty and Pierce (1961).

Water holding capacity. A number of methods have been used for determining muscle water holding capacity. Hamm (1960) listed some, including sedimentation, centrifugation, filtration, and pressing. The most commonly used is the press method of Grau and Hamm (1953) or a modification of this method. The centrifuge method by Wierbicki et al. (1957) has been used by several research groups.

Grau and Hamm (1953) described a method for measuring the moisture expressed from a 500 mg. sample of meat when it is subjected to a standardized pressure for a specified time. Various workers have modified the pressing time, pressure and method of pressing. Advantages of the press method claimed by Grau and Hamm (1956) are: 1. The procedure can be used for crushed or uncrushed muscle, and meat with and without the addition of foreign water (up to 100%); 2. Only 0.5 gram material is needed for quantitative work; 3. Little time required; 4. The results can be calculated from the "pressed image" at a later time; 5. The apparatus and procedure is simple. He stated that one through four are not possible with the centrifuge method. The press technique is commonly used to determine water holding capacity of raw meat and the centrifuge method is used for determination of the free moisture content of both heated and cooked meat.

Hamm (1959) stated the press method is a good method for measuring water holding capacity A good correlation was found between water holding capacity as measured by the press method and sausage quality although he does not explain this term. He could determine the usefulness of meat for sausage with his press technique. Wierbicki et al. (1957) found the centrifuge method useful for studying the expressed juices as well as the pH and ionic shifts which take place during processing.

The Water Holding Capacity of Meat

One of the most important factors of meat quality is its water holding capacity. Water holding capacity is related closely to taste, tenderness, pH, color, and other factors of meat quality and can be influenced by treatment before slaughter. In addition, water holding capacity of muscle affects the quality of meat during almost all processing operations (Hamm, 1960).

Hamm (1959) described water holding capacity as the ability of meat to hold fast its own or added water during application of any force---

pressing, heating, chewing or grinding. "Swelling" was defined as the uptake of water by meat from any surrounding fluid which causes an increase in volume or weight of muscle. Meat hydration is the interaction of water holding capacity and swelling is the force with which protein is capable of retaining water that it has taken up (Hamm 1959, 1953).

Water binding is primarily due to the electrical charge of protein and the attraction of water by polar groups. Water, being a dipole, acts as a molecular magnet as the negative charge of the oxygen does not coincide with the center of the positive charge of the hydrogens (Hamm 1953, 1959). Hamm (1959) describes two ways in which water is bound. First, the "net charge effect" which is due to the net charge of the protein, is of importance. Groups adding to the net charge could be free carboxyl, amino, hydroxyl or sulfhydryl groups. The "stereo effect" is the second method of binding water by protein. This is described as changes of meat hydration which are not due to changes in net charge. Certain cross chains, such as salt linkages, bivalent metal linkages, disulfide bonds and hydrogen bonds, are not available to water because of "steric" and spatial reasons. By cleavage of the cross linkages the peptide chains become more flexible and water can now attach to the polar groups.

The direct electrostatic binding of water to protein is very firm. Some loosely bound water is also present (Hamm, 1953). There is now reason to believe that several layers of water may be bound to the protein charges. Some water is attracted by the primarily bound water dipoles while other water is taken up by capillary forces.

Factors Related to the Water Holding Capacity of Meat

pH. Water holding capacity is directly related to pH as related by Hamm, 1953, 1959; Grau and Hamm, 1953; Swift and Berman, 1959; and Wierbicki et al. 1958. Known causes of variation in the pH values of meat include differences in lactic acid formation after slaughter, age at slaughter and degree of aging of meat (Swift and Berman, 1959). pH and water holding capacity are highest at time of slaughter. For the next 24 to 48 hours the pH drops due to the formation of lactic acid, loss of ATP and decrease in electrical activity (Hamm, 1959; Wilson, 1959). At the same time the sarcolemma loses some of its semi-permeable characteristics and a freer interchange of electrolytes take place. Hamm (1959) stated that one third of the pH change is due to breakdown of ATP. With further aging, autolysis will bring about cleavage of some bonds and water holding capacity will be increased by the stereo effect (Hamm, 1959). There is a redistribution of ions within the muscle.

The effect of pH is explained by the net charge. The farther the pH is from the esoelectric point (the number of positive charges equals the number of negative charges), the greater the water holding capacity. In muscle the isoelectric point is around pH 5 and there will be minimum hydration and swelling at this point (Hamm, 1953 and 1959).

Swift and Berman (1960) found glycogen and buffering capacity to vary among 8 muscles studied. The variation followed a definite pattern with regard to pH and water retention. A highly significant correlation was found between buffering capacity and pH. All muscles contained residual glycogen at the ultimate pH. Therefore, the relatively high characteristic pH of certain of the muscles could not be simply attributed to lack of glycogen.

Color. Water holding capacity may have considerable influence on meat color. The change in color with changing pH is attributed less to change in pigment content and more to differences in light penetration (Winkler, 1939; Bate-Smith, 1948; and Lawrie, 1958). There is a more open structure of the muscle near the isoelectric point. Light penetration will be deeper, more light will be scattered and the color will appear lighter. With higher pH, muscle will be swelled due to hydration, less scattering of light will take place and the color will appear darker (Lawrie, 1958).

Electrolyte content. Hamm (1959) found that despite their low concentration, magnesium, calcium, and perhaps zinc have an effect on water holding capacity. With the removal of calcium there is an increase in water holding capacity. By removing metallic cross linkages more charged groups become available for water binding. The removal of bivalent ions is a typical case of a stereo effect.

Swift and Berman (1959) found a statistically significant correlation between water retention and pH and zinc content. An inverse relationship was found to calcium, magnesium and potassium. This indicates that zinc may differ from the other ions in an important aspect. It was suggested that zinc may participate in the determination of pH as a component of an enzyme system.

ATP. There is a high adenosinetriphosphate (ATP) content in meat at slaughter. The ATP content diminishes as it is broken down to adenosinediphosphate (ADP), adenosinmonophosphate (AMP) and finally inorganic monophospate (IMP) after deamination. ATP has the ability to form complexes with alkaline earth metals and thus ties up a part of the bivalent ions. With the breakdown of ATP, the bound cations are released and become part of the protein structure. This gives a tighter structure with less hydration (Hamm, 1959).

Salts. Up to concentrations of approximately 4 percent the water holding capacity of the muscle increases greatly with increasing salt additions. When more than 4 to 5 percent salt is added the water holding capacity decreases and the protein shrinks and gives off water (Hamm, 1953). Addition of salt will always increase the water holding capacity of muscle protein, as long as the salt concentration remains such that the maximum swelling and water holding capacity is not exceeded (Hamm, 1953). Salt cross linkages may be split off by the binding of chloride ions causing an increase in meat hydration by the "net" and "stereo" effect. Sodium has little effect (Hamm, 1959). Hamm (1959) stated the effects of other salts could be predicted by examining their chemical formula.

Phosphate. Opionions differ as to the influence of phosphates on water holding capacigy. Some workers have found no action while others report results only with specific phosphates. Hellendoorn (1962) stated this difference in opinion can be explained by the different methods adopted and by not using practical concentrations in conjunction with sodium chloride at the proper pH. The action of phosphate is generally thought to: 1. influence (raise) the pH; 2. tie up bivalent cations in meat; 3. resemble the action of ATP by splitting actomyosin to actin and myosin, resulting in a swelling action with the uptake of water (Hamm, 1959; Hellendoorn, 1962). There is little or no action below pH 5.5, however.

Location of the Muscle. Water holding capacity is influenced by the location of the muscle, function of the muscle and the physiology of the muscle (Hamm, 1960). Muscles high in connective tissue have higher water holding capacities (Hamm, 1953). Swift and Berman (1959) studied water retention properties of eight different bovine muscles. Considerable variation existed with respect to water retention and pH, nitrogen, fat, moisture or electrolyte content of the muscles. The muscles followed a trend with regard to water retention, pH and other properties. In a later report (1960) patterns and variations were demonstrated between the eight muscles for glycogen content and buffering capacity. Buffering capacity is used as a measure of the ability of a muscle to resist a change in pH by the addition of alkali. It was largest in muscles of characteristically low pH and a highly significant negative correlation was found between it and pH. Buffering minimized the pH differences anticipated from the amount of glycolysis occurring in different muscles. Residual glycogen was highest in muscles attaining the lowest ultimate pH.

The Influence of Water Holding Capacity on Meat Quality

Deatherage (1955) has reported that tenderness, juiciness, color, taste and shrinkage on cooking and drip on freezing and thawing appear to be directly related to the water holding capacity of meat.

A relationship should exist between water holding capacity and juiciness; however, an exact measure of juiciness has not been established. It is expected that not the amount of expressible water but the amount of water bound to the coagulated muscle tissue (not expressible juice) is related to the subjective impression of "juiciness" (Hamm, 1960).

Part of the variation in tenderness may be due to water holding capacity. The structure of the proteins is looser when more water is bound. Meat is least tender at its isoelectric point (Deatherage, 1957; Hamm, 1960).

Hamm (1960) reported water holding capacity may influence taste. Water soluble flavoring substances may be lost along with juice loss during processing and cooking.

The relationship of water holding capacity to color has already been explained.

The relationship of beef carcass quality factors or indicators to eating characteristics of the meat is of prime importance not only to the consumer, but, to the livestock feeder, packer and meat retailer. Differences in opinion regarding the importance of such factors have been noted in the literature. In this study correlation coefficients have been calculated between a number of physical and chemical "indicators" of beef quality and cooking and sensory data. In addition, an attempt has been made to relate carcass maturity to bone ossification.

EXPERIMENTAL METHODS

History of Animals

Beef wholesale rib cuts were used from 32 steers that were randomly selected from a group of sixty-five Hereford steers to represent three sire groups. This group of animals was originally used for an animal breeding study. The animals were long yearlings at the time of slaughter and had been managed and fed as a group from birth to slaughter. They were weaned in mid-September, 1961, and wintered on a concentrate - roughage ration until April 1, 1962. They were then put on full feed and fed until August 16, 1962. Average weight at time of slaughter was 1004 pounds.

The cattle were owned and fed by Cliff Houghton of Tipton, Kansas, and slaughtered by the Maurer-Neuer division of the John Morrell Company in Kansas City. They were slaughtered August 17, 1962 and the 32 ribs were shipped to the meat laboratory at Kansas State University for further processing. The carcasses were graded to the nearest one-third of a grade by a Federal Meat Grader (Table 2).

Handling and Cutting Procedure

Upon arrival at the meat laboratory the ribs were stored at 36 - 38° F. until processed (2-3 days). The 12th rib was removed for color, water holding capacity, pH and cooking data. The 9-10-11th ribs were physically separated into fat, lean and bone and the rib eyes used for chemical analysis. Personnel of the Foods and Nutrition Department cooked and collected cooking and sensory data on the 6-7-8th rib portions.

Samples of <u>longissimus dorsi</u> muscle (just posterior to the ninth rib) were ground three times through the 1/8 inch plate with an Oster electric meat grinder. After grinding the samples were wrapped in polyethylene-coated freezer paper and stored at 0° F. until analyzed.

Color, pH and water holding capacity were determined within a few hours after cutting on fresh muscle samples. Moisture and ether extract were determined after several months freezer storage. Protein was not analyzed until samples had been freezer stored for one year.

Marbling Determination

Marbling of the rib eye at the 12th rib was determined subjectively by a Federal Grader when the carcasses were graded. During processing, marbling was estimated at the ninth rib, being closer to where the samples were taken for chemical analysis. A number was given to each one-third of a degree of marbling with a higher number for a greater degree of marbling (Table 1).

Moisture and Ether Extract Determination

Total moisture and fat content were determined with a modified AOAC (1960) procedure. Extraction thimbles were dried at 100° C., cooled in a desiccator and weighed. Approximately a 3 gram sample was then weighed into the thimble to the nearest 0.0001 gram on a Gram-atic automatic balance. Samples were run in triplicate and dried in a vacuum oven at 98° C., cooled in a desiccator, weighed and total water calculated as loss in weight. The same thimbles were then extracted for 12 hours in a Soxhlet extractor using low boiling petroleum ether and redried. They were then reweighed and additional weight loss was expressed as percent ether extract.

pH Determination

pH determinations were made using a Beckman Zeromatic pH meter. The electrode was pressed into the lean at three locations and readings were made. Average figures were used.

Table 1. Marbling score system

	+	Average	-
Extremely abundant	36	35	34
Very abundant	33	32	31
Abundant	30	29	28
Moderately abundant	27	26	25
Slightly abundant	24	23	22
Moderate	21	20	19
Modest	18	17	16
Small	15	14	13
Slight	12	11	10
Traces	9	8	7
Practically devoid	6	5	4
Devoid	3	2	1

Table 2. Quality grade scoring system

	+	Average	-
Choice	12	11	10
Good	9	8	7
Standard	6	5	4
Utility	3	2	1

Color Determination

A photovolt reflectance meter was used to determine percent reflectance from the muscle samples. Readings were taken using a green filter and scale readings were used as a comparison. A factor of two was used to bring the reading to a more sensitive part of the scale. The higher the reading, the greater the reflectance and lighter the color. Readings were taken in triplicate the same day the samples were cut.

Protein Determination

Nitrogen was determined with the AOAC (1960) Kjeldahl nitrogen procedure. Nitrogen times 6.25 was considered to be percent protein. Determinations were made in cooked and raw samples. In addition, moisture to protein ratios were calculated.

Determination of Water Holding Capacity

Water holding capacity was determined by three methods: 1. A modification of the expressible moisture determination of Hamm (1956) was used. Muscle samples of approximately 0.3 grams were used. Whatman number 1 filter paper was kept in a desiccator over saturated potassium chloride solution to maintain a standard humidity. After the samples were weighed, a single sheet of paper was removed from the desiccator and the sample placed in the center. The paper was then placed between two plexiglass plates and pressed in a Carver press for 5 minutes at 4,000 pounds per square inch pressure. After pressing the meat area was marked on each paper with a red pencil. The muscle and water areas were measured with a compensating polar planimeter. Results were expressed as square inches of moisture area (not meat film area) per gram of sample. Determinations were made in triplicate.

2. This procedure was similar to the above. However, instead of the Carver Press, balance weights were used. Samples were placed on filter paper between plexiglass plates and a 1000 gram weight was placed on top for one minute. Results were calculated as above.

3. The final method used for expressible moisture determination was a modification of the centrifuge method of Wierbicki et al. (1957). A 10 to 15 gram ground meat sample was placed in a polyethylene centrifuge tube, stoppered with a capillary tube in a rubber stopper and placed in a 70° C. water bath for 30 minutes. The cooked meat sample was removed and placed in a fritted glass bottomed crucible. Juice from cooking was left in the polyethylene tube and the crucible was taped to the top and centrifuged at 3,000 RPM for 5 minutes. Expressed juice was poured off into a volumetric cylinder and the volume recorded. Water content of the juice was determined and results were recorded as percent expressible moisture.

Penetrometer Readings

Samples of the distal portion of the spinus process ("buttons") were obtained during physical separation of the 9-10-11th ribs, and placed in envelopes in a "wet" desiccator. Penetrometer readings were taken at two locations with a "Precision" laboratory penetrometer using a sharp needle and 125 grams added weight for 15 seconds. The scale was calibrated in tenths of millimeters, thus each value recorded was the depth of penetration in the cartilage.

Calcium Determination

Calcium determinations were made on "buttons" samples which were stored at 0° F. until analysis. Samples were extracted for 12 hours in petroleum ether to remove fat and dried 8 hours at approximately 100° F. in a drying oven to remove moisture. They were then cooled and weighed to obtain dry bone weight. The dried samples were then placed in Coors 230 (size) crucibles (previously brought to standard weight) and ashed in a muffle furnace at 650° C. until a light colored material was left. Calcium was determined on the ash using the AOAC (1960, page 292) method. Results were calculated on the percent of calcium in ash as well as in dried cartilage.

Cooking Procedure - 12th Rib

A simple cooking procedure was used to measure drip and evaporation loss. Moisture and protein determinations were later run on these samples. Approximately a one-eighth inch slice was removed from the twelfth rib samples with a slicing machine, folded in a uniform manner and weighed to the nearest gram. The samples were cooked at 300°F. for one hour in individual sample bottles and supported by wire mesh racks made from ¼ inch hardware cloth. Drip and evaporation loss was determined by changes in weight. Bottles were then capped, placed in freezer and held at 0° F. until chemical analysis was made.

Cooking and Sensory Procedure

The 6-7-8th rib roasts were cooked and evaluated for sensory properties by personnel of the Foods and Nutrition Department. All roasts were cooked to 158° F. and cooking time was recorded. In addition, cooking loss was measured. Tenderness was measured with a Warner-Bratzler shear using one-inch cores from the longissimus dorsi. A seven point scale was used for panel evaluation. The higher the score the more desirable the tenderness, juiciness and flavor. A sample of the score card is shown in Table 3. Meat samples were cut into one-half inch cubes and served cold. The average panel score for each quality attribute was used for statistical analysis. Press fluid was determined as an objective measure of juiciness.

Statistical Analysis

Calculating the relationships of the various quality factors and estimators to cooking and sensory data was the main objective. Simple correlation coefficients were run between all 36 variables by the statistical laboratory. A 1410 IBM computor was used. According to Snedecor (1956 p. 174) correlations of 0.449 and 0.349 are required for significance to the 0.01 and 0.05 levels with 32 observations.

RESULTS AND DISCUSSION

Factors Related to Sensory and Cooking Data

All possible correlations were run between the 36 variables presented in this study including the relationship of physical and chemical factors to cooking and sensory data. Sensory data consisted of subjective flavor, juiciness and tenderness scores. Cooking data included cooking time, and drip and evaporation losses. Press fluid and Warner-Bratzler shear values were used as objective measurements of juiciness and tenderness.

Table 3. Sample of taste panel data sheet

SCORE CARD FOR BEEF

Judge ____________________ Code ______________ Date ______________

Sample No.	Desirability of Flavor		Juiciness	Tenderness			Comments
	Fat	Lean		Initial	Chews No.	Chews Score	
1							
2							
3							
4							

Descriptive terms for scoring

Desirability of Flavor

7. Very desirable
6. Desirable
5. Moderately desirable
4. Slightly desirable
3. Neutral
2. Slightly undesirable
1. Undesirable

Juiciness

7. Very juicy
6. Juicy
5. Moderately juicy
4. Slightly dry
3. Dry
2. Very dry
1. Extremely dry

Tenderness

7. Very tender
6. Tender
5. Moderately tender
4. Slightly tough
3. Tough
2. Very tough
1. Extremely tough

Subjective tenderness was broken down into three categories. Initial tenderness was recorded on the first bite. Secondly, the number of chews was counted. A final score was then made based on the number of chews.

A summary of the relationships found between the factors studied and sensory and cooking data is shown in Table 4.

pH. pH of the longissimus dorsi muscle (12th rib surface) varied from 5.38 to 5.92 among the 32 samples studied. The mean pH was 5.56. Significant relationships were not found between pH and sensory and cooking data. Correlations were low and insignificant as to sign. Other workers have noted a similar trend. Husaini (1950) found no relationship between pH and tenderness and Hedrick et al. (1959) found no relationship to cooking and sensory data.

Color. Objective muscle color, determined with a photovolt reflectance meter, showed a stronger relationship to sensory data. Correlations of 0.360*, 0.448** and 0.353* were found between color and lean flavor, juiciness and initial tenderness. A lighter muscle color was associated with a more desirable flavor, greater juiciness and higher initial tenderness score. All samples in this study had desirable color so a large color variation was not present.

Husaini et al. (1950) found no relationship between color and tenderness at 3 days post-mortem. A significant relationship existed at 15 days. Doty and Pierce (1961) found the opposite effect as color was more highly related to tenderness before aging. Color did not appear to

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* $P < .05$

**$P < .01$

Table 4. Simple correlation coefficients between quality factors and cooking and sensory data.

Character Studied vs.	Cooking time, min.	Cooking Losses			Shear Value	Press Fluid	Flavor		Juiciness	Tenderness		
		Total	Volatile	Drip			Fat	Lean		Initial	No. Chews	Final
pH	.256	-.122	.152	-.311	-.173	-.177	-.106	-.116	.043	.075	.083	.099
Color of lean	-.038	.062	.004	.080	.052	.080	.257	.360*	.448**	.353*	-.042	.313
WHC[a] Press	.264	-.047	.158	-.185	-.051	-.045	-.031	-.088	-.149	.008	.214	.035
WHC[a] Weight	-.129	.250	.142	.199	.104	.024	.073	-.004	.076	-.050	-.060	-.081
WHC[a] Centrifuge	.134	-.120	-.002	-.145	.466**	-.198	-.353*	-.537**	-.441*	-.589**	.164	-.589**
Marbling 12th rib	-.307	.289	-.003	.362*	.017	.170	.242	.144	.132	.205	.144	.200
Marbling 9th rib	-.168	.104	-.170	.289	.127	.020	.477**	.442*	.269	.356*	.168	.283
Ether extract	-.165	.131	-.007	.184	.006	.312	.017	.198	.363*	.132	.115	.075
% Moisture raw	.043	-.002	-.004	-.004	-.010	.073	-.269	-.221	-.123	-.114	-.124	-.102
% Moisture cooked	-.095	.156	.065	.131	.192	-.184	-.002	-.245	-.308	-.277	-.312	-.252
% Protein raw	.064	.138	.223	-.049	.103	-.069	-.136	-.081	-.188	-.040	-.202	.072
% Protein cooked	-.268	.184	.089	.166	.192	-.060	.155	-.049	-.124	-.055	.243	-.071
Moisture-protein (raw)	-.009	-.128	-.183	.018	-.118	.111	-.070	-.079	.065	-.046	.089	-.135
Moisture-protein (cooked)	.047	.044	.023	.020	.076	-.141	-.083	-.195	-.200	-.216	-.310	-.189
Grade	-.051	.127	.117	.133	-.035	-.106	.234	.098	.030	.155	-.036	.168
Age in days	-.236	.266	.031	.308	-.110	-.065	.184	.243	.210	.089	-.167	.019

*P < .05

**P < .01

[a]Water holding capacity

influence tenderness in animals of similar age and finish as reported by Hedrick et al. (1959).

No trend was shown for a relationship between color and the objective tests; namely press fluid and shear force. A high correlation (r = -.74) was noted by Kropf and Graf (1959A) between subjective color and shear force.

Water Holding Capacity. Correlations between expressible moisture by the weight and press methods, and subjective and objective sensory evaluations were non-significant. In addition, their signs were inconsistent. Water holding capacity as determined by the press and weight methods were run on fresh samples only.

A number of significant relationships were found between sensory and cooking data versus the centrifuge method of determining expressible moisture. Results obtained by the centrifuge method were related to shear force (r = 0.466**), initial tenderness (r = -.589**) and final tenderness (r = -.589**) scores. A relationship also existed between flavor of fat and flavor of lean versus this method as correlations of -.353* and -.537** were observed. Juiciness showed a relationship of -.441* to the centrifuge method.

As percent expressible moisture increased there was a trend toward decreased panel and objective sensory ratings. In other words, as water holding capacity increased (decreased expressible moisture) sensory acceptability also increased. The positive relationship to shear value can be explained by the method of coding. Higher scores are more desirable for the taste panel and lower scores are considered more desirable shear values.

Expressible moisture as determined by the centrifuge method was a better indicator of eating quality in this study than results obtained by the press and weight methods. This supports some of the views of Hamm (1960) as juiciness and tenderness were related to water holding capacity in cooked meat samples (centrifuge). Other factors must have played a more important role in the raw samples (press and weight methods). A correlation was expected between water holding capacity of cooked meat and its juiciness. Hypothetically, the more water meat contains and the tighter this water is bound to the coagulated tissue, the more juicy the meat should be. In addition, a relationship should exist between water holding capacity and tenderness, as processes that cause a loosening in muscle protein structure also increase water holding capacity (Hamm, 1960). This relationship to tenderness appears only when the difference in water holding capacity is relatively great between samples.

Hamm (1960) further states that the question of a relationship between water holding capacity and juiciness can be solved only by critical measurement of (1) the water holding capacity of raw meat (2) the amount of water released during cooking, and (3) the water holding capacity of the cooked meat in comparison with the subjective scores.

Marbling Scores and Ether Extract. Marbling scores appeared to be more closely related to sensory characteristics than was percent ether extract. Correlations between ether extract and sensory characteristics were non-significant in most cases. However, values of 0.312 and 0.363* were found between ether extract, and press fluid and juiciness. Correlations of 0.289, 0.477**, 0.442*, 0.269 and 0.356* were found between ninth rib marbling score and percent drip loss, fat flavor, lean flavor, juiciness and initial tenderness. The same factors as related to

12th rib marbling scores gave values of 0.362*, 0.242, 0.144, 0.132 and 0.205. Marbling scores at the ninth rib were slightly lower, but may more closely approximate that found in the samples analyzed for sensory data and ether extract. Samples of longissimus dorsi, removed just posterior to the ninth rib surface were used for chemical analysis. Ninth and 12th rib marbling scores were estimated by two separate individuals and were not significantly related (r = 0.287). The 12th rib location was scored by a Government Grader and the ninth rib eye muscle was scored for marbling during analysis at the meat laboratory.

Marbling at the ninth rib accounted for about 13 percent of the variance in initial panel tenderness and 7 percent of the variance in juiciness. At the 12th rib the values were 4 and 2 percent for the same factors. Some workers suggest a stronger relationship of marbling to juiciness than tenderness. Blumer (1963) in summarizing reports by a number of workers found marbling accounted for about 5 percent of the variance in tenderness and 14 percent of the variance in juiciness when prorated according to the number of samples in each study. Among the studies he quoted, marbling accounted for 0.01 to 36 percent of the variance in tenderness. There has been much disagreement among research workers regarding the emphasis to place on marbling as a predictor of increased sensory acceptability.

Moisture and Protein. In this study, percent moisture, protein as well as their ratio did not appear to be closely related to cooking and sensory data. No specific trends were noted as correlations were all low. Percent protein in the raw as well as the in cooked samples was not significantly related to sensory data. For the most part the same was true for moisture content. The percent moisture in the cooked samples showed low relationships to juiciness and initial tenderness with correlations of 0.308 and 0.277. In addition, moisture to protein ratios showed low, non-significant relationships to sensory and cooking data.

Percent moisture and protein were quite uniform between samples. Moisture varied from 69.03 to 74.55 percent and protein varied from 21.40 to 23.01 percent in the raw samples. The moisture to protein ratio (raw) ranged from 3.19 to 3.48. A greater range in percent protein and moisture among samples may have produced a closer relationship to sensory and cooking data.

Grade and Age. Grade and age were not significantly related to cooking and sensory data. Correlations were low between grade and initial tenderness ($r = 0.155$), juiciness ($r = 0.030$), flavor of fat ($r = -.234$) and flavor of lean ($r = 0.098$). Age was related to the same factors by correlations of 0.089, 0.210, 0.184 and 0.243 respectively. Low relationships were expected as the range in grade and age was small. Grade varied from "high standard" to "high good" while age varied from 509 to 581 days.

Various trends have been noted with changes in animal age. Fat (marbling) usually increases with age while protein and moisture decrease (Hankins, 1945). Tenderness has been reported to decrease with increased animal age by Hiner and Hankins (1950), Alsmeyer et al. (1959) and Tuma et al. (1962). Kropf and Graf (1959A) and Simone et al. (1959) reported color to increase in intensity with advancing age. Flavor and juiciness were effected less by age than tenderness as reported by Simone et al. (1959) and Tuma et al. (1963).

Similar feeding and management reduce the effect of grade as an indicator of tenderness (Husaini, 1950). Cover et al. (1958) concluded that carcass grade was not a satisfactory indicator of tenderness, while Simone et al. (1959) and Kropf and Graf (1959A) reported increased tenderness with increased grade.

Quality Factors Versus Longissimus Dorsi Muscle Components

It was of interest to find what relationships existed between the factors studied and longissimus dorsi muscle composition or components. Samples for chemical analysis were obtained just posterior to the ninth rib surface. Muscle components studied were percent protein, moisture, moisture-protein ratio and ether extract. Protein and moisture were determined on raw as well as cooked samples. The relationships between quality factors and muscle components are summarized in Table 6.

Significant relationships were not found between pH and muscle components. A correlation of -.352* was found between color and percent protein (raw). Other correlations between color and muscle components were non-significant.

Water holding capacity might be expected to show a relationship to composition. The relationship to percent moisture (raw) was 0.113 for the press method. This increased to 0.233 and 0.391* for the weight and centrifuge methods. Slightly higher correlations were noted between moisture (cooked) and water holding capacity as determined by the press (r = 0.312), weight (r = 0.295) and centrifuge (r = 0.362*) methods. The centrifuge method may be more closely related to percent moisture. Hamm (1960) concluded that water holding capacity is not correlated to the total moisture content of meat.

Percent protein was not significantly related to water holding capacity. All values were low, however, those obtained with the press

Table 5. Mean values for the 36 variables studied.

Number	Characteristic	Mean Value	Range
1	pH	5.56	5.38 - 5.92
2	Color - Photovolt readings[a]	14.84	12.00 - 16.70
3	WHC[b] - press (sq.in.juice area/gram of tissue)	11.16	9.21 - 14.35
4	WHC - Weight (sq.in.juice area/gram of tissue)	3.03	1.79 - 4.09
5	WHC - Centrifuge (percent expressible moisture)	45.74	40.22 - 51.01
6	Percent moisture raw	72.58	69.03 - 74.55
7	Percent protein raw	22.02	21.14 - 23.01
8	Percent moisture cooked	55.45	40.56 - 64.83
9	Percent protein cooked	28.36	22.89 - 31.15
10	Moisture - protein ratio raw	3.30	3.19 - 3.48
11	Moisture - protein ratio cooked	1.97	1.38 - 2.65
12	Percent ether extract	6.48	3.75 - 12.19
13	Percent drip loss[c]	10.02	6.78 - 16.78
14	Percent evaporation loss[c]	14.78	10.48 - 23.08
15	Percent total cooking loss[c]	25.11	19.7 - 30.87
16	U.S.D.A. Grade[e]	7.50	6 - 9
17	Marbling score - 9th rib	9.34	7 - 13
18	Age in days	555	509 - 581
19	Penetrometer reading - center (M.M.'s X 10^{-1})	8.59	3.7 - 21.3
20	Penetrometer reading - tip (M.M.'s X 10^{-1})	6.97	2.3 - 17.0
21	Penetrometer reading - average (M.M.'s X 10^{-1})	7.83	3.4 - 18.2
22	Percent Ca in Ash	10.64	3.44 - 23.10
23	Percent Ca in dry bone	0.475	0.11 - 1.57
24	Cooking time - minutes[f]	38.00	33.7 - 43.8
25	Percent total cooking losses[f]	23.35	21.0 - 25.2
26	Percent volatile cooking loss[f]	18.33	17.1 - 20.4
27	Percent drip loss[f]	5.02	3.0 - 8.0
28	Shear value (lbs. to shear 1" core)	16.77	12.6 - 26.4
29	Press fluid (ml./25 gr.)	8.03	7.2 - 9.3
30	Subjective flavor of fat	5.64	5.0 - 6.1
31	Subjective flavor of lean	5.87	5.0 - 6.4
32	Subjective juiciness	5.54	4.3 - 6.2
33	Subjective tenderness (initial)	5.59	4.0 - 6.3
34	Subjective chew count (number)	30.25	21 - 40
35	Subjective tenderness (final)	5.53	4.0 - 6.3
36	Marbling score, 12th rib[d]	10.88	8 - 14

[a]Using green tristimulus filter.
[b]Water holding capacity.
[c]12th rib sample.
[d]As outlined in Table 1.
[e]As outlined in Table 2.
[f]6-7-8 rib roast.

method were slightly higher than results obtained by the weight or centrifuge method. Moisture to protein ratios versus water holding capacity were insignificantly correlated for raw samples. Values of -.423*, 0.301 and 0.319 were obtained for moisture to protein ratio (cooked samples) versus the press, weight and centrifuge method of determining water holding capacity.

Hamm (1960) claims "no relationship" seems to exist between water holding capacity and protein content. Swift and Berman (1959) found that an increase in moisture-protein ratio of beef muscles was directly associated with increasing water retention and that a significant negative relationship existed between water retention and protein content. The number of animals in their study was small (5) and therefore a definite conclusion could not be drawn.

Water holding capacity, in addition was not significantly related to percent ether extract. According to Hamm (1960) the intramuscular fat content of meat seems to influence the water holding capacity. Wanderstock and Miller (1948) found that as carcass finish increases, expressible juice decreases. Meat with a higher intramuscular fat content should tend to have a higher water holding capacity. Water holding capacity by the three methods studied was not strongly related to moisture, protein and fat content of the samples studied.

Inconsistent relationships to composition were shown by subjective marbling scores. Correlations of -.526**, -.343, -.394* and 0.334* were found between marbling at the ninth rib and percent moisture (raw), moisture (cooked), protein (raw) and ether extract. The same characteristics versus 12th rib marbling were -.338*, -.082, -.216 and -.215. Marbling measured at the ninth rib appeared more closely related to

Table 6. Simple correlation coefficients between quality factors and muscle components in the <u>longissimus</u> <u>dorsi</u> (posterior to 9th rib).

Character vs	% Moisture raw	cooked	% protein raw	cooked	Moisture/Protein raw	cooked	% Ether Extract
pH	-.122	.030	.195	-.208	-.264	.132	-.084
Color	-.151	-.067	.352*	-.064	.208	-.041	.162
WHC Press	.113	.312	.242	.301	-.125	-.423*	-.197
WHC Weight	.233	.295	-.148	-.057	.275	.301	.039
WHC Centrifuge	.391*	.362*	.075	-.004	.184	.319	-.141
Grade	-.435*	-.102	-.196	-.089	-.114	-.044	.134
Marbling 9th	-.526**	-.343	-.394*	-.105	-.022	-.242	.334*
Marbling 12th	-.338*	-.082	-.216	-.021	-.045	-.045	.215
Age in days	.064	.157	-.383*	-.079	.364*	.176	.134

*P < .05

**P ∠ .01

muscle moisture, protein and ether extract. The relationship of marbling to percent ether extract was lower than might be expected. The existence of fat particles not visible as marbling or the presence of other ether soluble substances could explain this. Ether extract measures not only visible flecks of fat, but, fat deposits along seams of connective tissue and fat not visible as marbling. In addition, ether soluble substances which are not true fats are also included (Cover et al., 1956). A negative relationship of marbling to moisture content was expected. The poor relationship of marbling to protein and moisture - protein ratio might not have existed if a wider range of degrees of marbling had been present.

A weak relationship was found between grade or age and composition. Grade and percent moisture in the longissimus dorsi muscle (raw) were negatively correlated (r = -.435*). As grade increased, moisture content decreased or in other words fat content increased. Age showed some relationship to protein content (raw) with a significant negative correlation of -.383*. In addition, a relationship existed between age and moisture - protein ratio (raw) as a significant negative correlation of -.364* was observed. Mean values and range for composition are shown in Table 5.

Objective and Subjective Tests

It would be desirable if objective tests could be developed that are accurate predictors of sensory characteristics of meat. The relationships of subjective tests to objective measures of similar characteristics are of prime importance in developing such tests. Objective evaluations used in this study included Warner-Bratzler shear value, press fluid volume, percent ether extract in the <u>longissimus dorsi</u> muscle, water holding capacity determinations and percent cooking loss. Correlation coefficients between objective tests and subjective sensory data are shown in Table 7. The relationship of water holding capacity to sensory evaluations has been covered in an earlier section (Table 4).

Shear value was a good indicator of tenderness in this study. Correlations of -.660**, 0.351* and -.703** were exhibited between shear value and initial tenderness, chews count and final tenderness values. Twenty-one percent of the variability in final tenderness score was accounted for by the Warner-Bratzler shear. In addition, significant negative correlations were found between shear values versus flavor of lean (r = -.479**) and juiciness (r = -.339*). The Warner-Bratzler shear has been widely used as an objective measure of tenderness. Pearson (1963) states that the correlation between shear readings and panel tenderness is around 0.75 (average).

Press fluid was not significantly related to juiciness (r = -.255) or other sensory tests. Other workers have found little relationship between subjective and objective measures of juiciness (Satorium and Child, 1938; Hall <u>et al</u>., 1944; and Gaddis <u>et al</u>., 1950). Subjective juiciness scores and the amount of press fluid do not appear to represent the same thing (Gaddis <u>et al</u>., 1950). Hamm (1960) states it is not the amount of expressible water, but the amount of water bound to the coagulated muscle tissue that is related to subjective juiciness.

Correlations of 0.334 and 0.363* were found between ether extract versus ninth rib marbling, and juiciness. Ether extract was weakly correlated (r = 0.216) to 12th rib marbling. The greater relationships between marbling in the <u>longissimus dorsi</u> muscle at the ninth rib and

Table 7. Simple correlation coefficients between subjective and objective measurements.

Character vs.	Marbling score L. D. 9th rib	Marbling score L. D. 12th rib	Subjective flavor of fat	Flavor of lean	Juiciness	Subjective tenderness Initial	Subjective tenderness Chews	Subjective tenderness Final
Shear value	-.128	.017	-.206	-.479**	-.339*	-.660**	-.351*	-.703**
Press fluid	.020	-.170	-.032	.149	.255	-.025	.128	.019
% Ether extract	.334	.216	.017	.198	.363*	.132	.115	.075
Total cooking loss	.104	.289	.158	.340	.180	.281	-.306	.320
Volatile cooking loss	-.170	-.003	-.020	.191	-.017	.104	-.031	.125
Drip cooking loss	.289	.362*	.212	.258	.240	.250	-.339*	.279

*P < .05

**P < .01

ether extract could be due to a marbling gradient within the rib or to the closer proximity of the ninth rib to the sampling area. Marbling scores were slightly lower at the ninth rib as compared to the 12th rib. Ether extract was not significantly related to tenderness.

A method using a small sample of muscle from the 12th rib *longissimus dorsi* surface was tested as an estimator of actual cooking losses. Cooking loss figures obtained by this method did not appear to be related to actual losses from the 6-7-8-rib roast (Table 8). This method of cooking a thin slice of *longissimus dorsi* muscle was not a good indicator for predicting cooking losses as all correlations between values obtained by each method were low and non-significant. The relationship of surface area exposed to sample weight may have been a critical factor. This ratio was higher for the small samples and lower for the 6-7-8-rib roasts.

Significant correlations were found between total cooking loss (both methods) and lean flavor. The values were 0.408* and 0.340 for the 12th rib and the standard cooking method respectively. With the conventional roasting procedure, cooking time affected total cooking loss ($r = -0.452$**) and drip loss was related to marbling in the 12th rib eye muscle ($r = 0.362$*). Cooking loss scores were not significantly related to juiciness. Volatile cooking loss showed the lowest strength of relationship to other factors. Flavor was related ($r = 0.340$) to total cooking loss. The relationships of cooking losses to sensory evaluations are shown in Table 7.

Table 8. Simple correlation coefficients between cooking losses obtained by 2 methods.

12th rib[1] Cooking method	vs	Conventional roasting 6-7-8 rib roast (1)	(2)	(3)
(1) Percent drip loss		.152	.064	.164
(2) Percent volatile loss		.070	.025	.066
(3) Percent total loss		.160	.015	.129

[1]A small slice of longissimus dorsi from the 12th rib section.

Interrelationships Between Quality Factors

Water Holding Capacity. One of the objectives of this study was to determine the relationship between three methods of determining water holding capacity. It is not clear whether or not they measure the same characteristics of meat.

The relationships between these methods of measuring water holding capacity were non-significant (Table 9). Results may have been closer if water holding capacity by the press and weight method had been calculated in percent free water rather than square inches of juice area per gram of sample. As mentioned earlier, the centrifuge method was a better indicator of eating quality. Water holding capacity by the weight method was highly correlated to pH (r = -.473). Little indication appeared (Table 6 a 10) for a relationship of water holding capacity to percent moisture, protein and their ratio as correlations were non-significant in most cases. It appeared that the three methods did not measure the same muscle properties.

Table 9. Simple correlation coefficients between three methods of determining water holding capacity.

	WHC Press	WHC Weight	WHC Centrifuge
WHC Press		-.254	-.102
WHC Weight			.260

pH and Color. Color and pH were not significantly related (r = -.281). This was possibly due to the narrow pH range and the desirable color of all samples studied. Winkler (1939) reported a darkening in color with the rise in muscle pH. Relationships of pH and color to most other quality factors studied were also low and non-significant. pH was related to water holding capacity as determined by the weight method (r = -.473) but not the press or centrifuge methods. Hamm (1960) states that water holding capacity (press method) is not related to pH within the pH range 5.4 to 5.8, however, at pH values greater than 5.8 water holding capacity increases significantly with pH. A highly significant correlation was observed between color and marbling in the *longissimus dorsi* at the 12th rib (r = 0.470**). Color and grade were not significantly related (r = 0.337). It would appear that color may have been considered in grading.

Ether Extract and Marbling. Marbling scores at the ninth and 12th rib were related (r = 0.398* and 0.799**) to grade. At the ninth rib, marbling was related (r = 0.492**) to centrifuge water holding capacity. Relationships between ether extract and marbling scores at the ninth and 12th rib were 0.334 and 0.215 respectively. It should be remembered

Table 10. Interrelationships between quality factors studied.

Character Studied	vs. (2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)
(1) pH	-.281	-.118	-.473**	.003	-.122	.195	.030	-.208	-.264	.132	-.084	-.209	.132	-.303	.047
(2) Color of lean		-.031	.288	-.142	-.151	-.352*	-.067	-.064	.208	-.041	.162	.337	.101	.470**	.116
(3) WHC[a] press			-.254	-.102	.113	.242	-.312	.301	-.125	-.423*	-.197	.017	-.111	-.073	-.383*
(4) WHC[a] weight				.260	.233	-.148	.295	-.057	.275	.301	.039	.039	-.215	.211	.231
(5) WHC[a] centrifuge					.391*	.075	.362*	.004	.184	.319	-.141	-.297	-.492**	-.198	.004
(6) % moisture raw						.209	.249	.264	.493**	.075	-.363*	-.435*	-.526**	-.338	.064
(7) % protein raw							.049	.107	-.745**	-.002	-.472**	-.196	-.394*	-.215	-.383*
(8) % moisture cooked								-.028	.115	.855**	-.256	-.102	.343	-.082	.157
(9) % protein cooked									.091	-.537**	.060	-.089	-.105	-.021	-.079
(10) Moisture-protein raw										.040	.163	-.114	-.022	-.045	.364*
(11) Moisture-protein cooked											-.245	-.044	-.242	-.045	.176
(12) % ether extract												.134	.334	.216	.134
(13) Grade													.398*	.799**	.318
(14) Marbling at 9th rib														.287	.265
(15) Marbling at 12th rib															.039
(16) Age in days															

[a]Water holding capacity

*$P < .05$

**$P < .01$

that the samples of longissimus dorsi muscle for ether extract determination were taken just posterior to the ninth rib.

Age in Days. Age in days did not appear to be associated with many of the other quality factors. A negative relationship was shown between age and press water holding capacity (r = -.383*). Similar correlations were observed between age and percent protein (r = -.383*), and the moisture - protein ratio (r = -.364*) using raw samples. Again, it must be pointed out that a very narrow range of age in days is represented by this study. A summary of the interrelationships between quality factors are shown in Table 10.

Penetrometer Readings, Calcium Determinations and Maturity

Carcass maturity is of considerable importance to the meat grader as well as to the meat researcher. A good objective predictor of beef carcass maturity does not exist. Subjective carcass maturity is determined by shape, density and color of bones as well as color of flesh. Degree of ossification of the "buttons" (distal portion of the spinus process) is one of the main indexes used. Increased ossification is a sign of increased maturity in a carcass. The U.S. Meat Grading Service has divided carcass maturity into specific maturity groups depending on the factors mentioned above.

In this study a penetrometer was used to measure "button" hardness. In addition, percent calcium was determined using the same samples. "Button" samples were removed from the 9-10-11th rib section during physical separation. It was of interest to find out what relationship existed between percent calcium and penetrometer readings versus maturity (age in days). It was thought that penetrometer readings might be a good basis for an objective measure of maturity.

Penetrometer readings at the tip and center of the "button" as well as their average were not significantly related to age in days or carcass grade. Penetrometer readings were quite varied and appeared to be affected by bone porosity.

Percent calcium in the "buttons" was calculated on the dry bone weight basis as well as the ash weight basis. Correlations to age were low and non-significant for the most part. Percent calcium (dry bone) was significantly related to grade (r = 0.342*) but ash calcium was not.

It was difficult to determine calcium in "button" samples because of their light weight and low content of calcium. Because of their light weight, what appeared to be an adequate sample was actually too small for an accurate determination. A great variation in calcium content was observed. On the ash weight basis, calcium varied from 3.59 to 23.10 percent with most values below 15 percent. Percent calcium (percentage of dry bone) varied from 0.11 to 1.57 percent with a mean value to 0.475 percent. A relationship of 0.595** was observed between calcium in ash versus calcium in dry bone. The sample with close to the highest calcium content, based on ash weight (22.76 percent), ranked lowest in percent calcium on the dry bone basis (0.11 percent). In addition, upon ashing a true ash did not appear, but a yellow mass was observed.

One of the limitations of this study was the lack of range in age represented. Only a two month variation existed among the 32 samples. It would be interesting to note what relationship might exist for a

Table 11. Simple correlation coefficients between bone determinations and age and grade.

Character vs.	Age	Grade
Penetrometer reading - tip	-.031	-.003
Penetrometer reading - center	-.090	-.201
Penetrometer reading - average	-.062	-.082
Percent Ca in Ash	.165	-.025
Percent Ca - dry bone	-.180	.342*

*P < .05

**P < .01

larger, more varied population. Correlations between penetrometer readings, percent calcium, age and grade are shown in Table 11.

SUMMARY

In this study 32 wholesale beef ribs were randomly selected from 65 Hereford steers previously used for an animal breeding study. The 12th rib section was removed and used to obtain color, pH, water holding capacity and cooking data. The <u>longissimus</u> <u>dorsi</u> of the 9-10-11th rib section was used for chemical analysis and the 6-7-8th rib section was roasted to provide cooking and sensory data. In addition, "buttons" were removed from the 9-10-11th rib portion for penetrometer readings and calcium determinations. All possible correlation coefficients were calculated between the 36 variables presented in the study.

Relationships of physical and chemical factors to cooking and sensory data were studied. Age, grade, pH, and moisture/protein ratio were not good indicators of eating qualities. Color showed a stronger relationship to cooking and sensory data as a lighter color was associated with a more desirable flavor, greater juiciness and higher initial tenderness scores. Water holding capacity as measured by the centrifuge method was significantly related to shear tenderness, panel tenderness and panel juiciness. Little relationship seemed to exist between water holding capacity as measured by the press and weight methods and sensory characteristics. Marbling scores were more closely related to sensory data than ether extract was.

Few significant relationships were detected between quality factors and the muscle components studied. Color was significantly related to percent protein (raw) and grade showed a significant relationship to percent moisture (raw). Few significant relationships were noted between water holding capacity (3 methods) and percent protein and moisture in the longissimus dorsi muscle. Marbling scores were related to percent protein and moisture (raw). Age in days was significantly related to percent protein and the moisture - protein ratio (raw).

Shear value was a good predictor of subjective tenderness. It was also related to subjective juiciness and lean flavor. Press fluid was not significantly related to subjective juiciness. Ether extract appeared more closely related to marbling scores at the 9th rib than at the 12th rib. Percent cooking loss showed little relationship to subjective cooking data.

The relationships between three methods of measuring water holding capacity were non-significant. In addition, most other relationships between quality factors were low. Relationships between the muscle components (ether extract, moisture and protein) were significant.

Carcass maturity and grade were not related to penetrometer readings on the "buttons." Percent calcium ("buttons"), in addition, was not a good predictor of maturity.

More positive results in some cases might have been obtained if a greater sample variation had been present. The 32 ribs studied were close in age and grade as well as other physical and chemical characteristics.

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THE RELATIONSHIP OF CERTAIN PHYSICAL AND CHEMICAL FACTORS TO COOKING AND SENSORY EVALUATIONS OF BEEF

by

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Beef quality factors includes physical as well as chemical characteristics measured by visual appraisal, mechanical measurement and chemical analysis. In this study, the relationships between certain physical and chemical factors, and sensory and cooking data have been studied. In addition, an objective measure of carcass maturity has been tried.

A group of 32 wholesale beef ribs, from cattle of known history, ranging in grade from high "standard" to high "good" were used. The 12th rib portion was removed and used to obtain color, pH, water holding capacity (three methods) and cooking data. The <u>longissimus dorsi</u> of the 9-10-11 rib section was chemically analyzed for protein, moisture and ether extract. In addition, "buttons" (distal portion of the spinus process) were removed for penetrometer readings and calcium determinations. The 6-7-8 rib section was roasted and cooking data (cooking time and losses) and sensory evaluations by subjective panel and objective measures were obtained. All possible correlation coefficients were calculated between the 36 variables represented in this study.

Age, grade, pH and moisture-protein ratio were not good indicators of eating qualities. Color showed a stronger relationship to cooking and sensory data as a lighter color was associated with more desirable flavor ($r = 0.360^*$), greater juiciness ($r = 0.448^{**}$) and higher initial tenderness ($r = 0.353^*$) scores. Water holding capacity as measured by the centrifuge method was significantly related to shear tenderness ($r = 0.466^{**}$), panel tenderness ($r = 0.589^{**}$) and panel juiciness ($r = -.441^*$). Little relationship seemed to exist between water holding capacity, measured by the press and weight method, and sensory data. Marbling scores were more closely related to sensory characteristics than ether extract was.

Few significant relationships were detected between quality factors and the muscle components studied. Color was significantly related to percent protein (raw) and grade showed a significant correlation to percent moisture (raw). Few significant relationships were noted between water holding capacity (3 methods) and percent protein and moisture in the longissimus dorsi. Marbling scores were related to percent moisture and protein (raw). Age in days was significantly related to percent protein and the moisture-protein ratio (raw).

Shear values were a good predictor of subjective tenderness (r = -.703** final). It was also related to subjective juiciness and lean flavor. Press fluid was not significantly related to subjective juiciness. Ether extract was significantly related to marbling scores at the 9th rib but not 12th rib scores. Little relationship was shown between cooking losses and subjective cooking data.

The relationship between three methods of determining water holding capacity were non-significant. In addition, most other relationships between the quality factors studied were low. Significant correlations were found between the muscle components (ether extract, moisture and protein) studied.

Carcass maturity and grade were not related to penetrometer readings on the "buttons." Percent calcium ("buttons") in addition was not a good predictor of carcass maturity.

More positive results, in some cases, might have been obtained if a greater sample variation had been present. The 32 ribs studied were close in age and grade as well as other physical and chemical characteristics.