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RELATIONSHIP OF SUBJECTIVE INDICES OF QUALITY IN LAMB CARCASSES TO OBJECTIVE MEASUREMENTS OF QUALITY AND GRADE

by

JOHN CHARLES FORREST

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INTRODUCTION

Within the past five years lamb producers and packers have been engaged in a controversy over the grading of lamb carcasses. Members of some organizations of the livestock and meat industry have felt that the grading standards for lamb did not reflect the true quality of the carcasses since too few carcasses were eligible for the top grades. Federal grades for lamb carcasses were in danger of being suspended at one time as the result of pressure by some organizations for the discontinuation of lamb grading. A series of meetings was then held, where various segments of the industry were represented, to consider changes in the standards. In March 1960, the standards were amended to reduce both the conformation and quality requirements for the Prime and Choice grades, (USDA 1960).

The question now arises as to whether or not the present standards for grading lamb carcasses provide an effective tool for measuring the quality of meat in the carcass. When studying a grading system one should not lose sight of the purpose of grading which is to aid in determining the value of a product in terms of satisfaction to the ultimate consumer, through the application of a uniform set of standards. Ideally, grading also gives the consumer a means of expressing his desires to the producer through his demand of one grade in preference to another.

It is the purpose of this study to determine the relationship of subjective indicators of quality in the carcass to objective measurements of quality.

Two phases are involved in this study; one, hereafter referred to as the quality study, deals with the relationship between various subjective and objective measurements of carcass quality and their relationship to the sensory factors. The second phase, referred to as the lamb color study, was set up to determine the effect of pre-slaughter treatment and stress upon the various carcass quality factors with specific interest in lean tissue color and its effect on the determination of the maturity class of the carcass and on the final grade.

REVIEW OF LITERATURE

Historical Development of Lamb Grading

The grading of meat and meat animals grew out of the need for uniformity of classification and description of animals and carcasses for market reporting purposes. The first extensive effort to set up specifications and terms for the description of classes and grades of meat was by Hall of Illinois in 1910. According to Kiehl and Rhodes (1960), these standards found their first use in an endeavor to provide a national reporting service. The standards were not used extensively in regular commercial trade. They were used only as guides in specifications for filling contracts for some major steamship lines and by the purchasing departments of a number of federal and state institutions.

It is interesting to note that in these first standards for lamb grading (Hall, 1910), quality was an important consideration in the grading of ovine carcasses. He stated, "Although a carcass of high quality must be good in form and covering, it must in addition have proper quality of flesh and bone and good general appearance." Then he went on to describe the desired quality characteristics.

The United States Department of Agriculture continued investigations to broaden the foundation of these original standards and in November of 1925 tentative grades for dressed lamb, yearling mutton, and mutton, were issued in mimeographed form by the U.S.D.A. There were only minor modifications of specifications and terms compared to those originally proposed by Hall. During the next year these standards were published as a part of Department Bulletin No. 1470, entitled "Market Classes and Grades of Dressed Lamb and Mutton."

In 1926 and 1927 public hearings were held in various cities over the country, to which livestock producers, slaughterers, wholesale and retail meat dealers, agricultural college workers, and others interested in the livestock and meat industries were invited. The sentiment developed at these hearings was overwhelmingly in favor of the standardized grades as presented.

The standards which were officially put into effect on February 16, 1931 by the secretary of Agriculture, were essentially those that had been used continuously by the Department of Agriculture in its wholesale meat market reporting service since 1917. It had also been used for the grading of millions of pounds of meat purchased by Federal, State and private institutions and organizations.

The original official standards consisted of six grades, Prime or No. A-1, Choice or No. 1, Good or No. 2, Medium or No. 3, Common or No. 4, and Cull or No. 5. The first standards stood as they were initially promulgated for 11 years. In 1940 the first change was made when the designations Medium and Common were changed to Commercial and Utility respectively, according to U.S.D.A. (1960).

The first major change in the official standards was made in April 1951. At this time the Prime and Choice grades were combined and designated as Prime. The Good grade was renamed Choice and the top two-thirds of the Commercial grade was designated as Good. The lower one-third of the Commercial grade was combined with the top two-thirds of the Utility grade and designated as Utility, thereby eliminating the Commercial grade name. The lower one-third of the Utility grade was combined with the Cull grade and designated as Cull.

In February 1957 the standards were amended for the third time, by reducing the quality requirements for Prime and Choice grade carcasses from the more mature lambs only. The quality requirements for the Good grade were increased slightly, particularly for very young lamb carcasses. This amendment also made provision for all lamb carcasses with quality indications equivalent to the lower limit of the upper one-third of the Good grade to be graded Choice provided they had a development of conformation equivalent to the mid-point of the Choice grade or better. Practically all references to quantity of external finish and kidney and pelvic fat were eliminated from the standards.

The most recent changes, which were mentioned earlier, came about in March 1960, after some organizations had requested that grading of lamb and mutton carcasses be suspended. This time the conformation requirements for lambs in the Prime and Choice grades were reduced about one-half grade; for more mature lambs they were reduced in the Prime grade about one full grade. In the Ghoice grade it was reduced about two-thirds of a grade. In addition a minimum degree of external fat covering was prescribed for the Prime and Choice grades. The emphasis placed on internal factors considered in evaluating quality, was decreased by reducing the emphasis on feathering between the ribs, eliminating consideration of overflow fat, and increasing emphasis on firmness of fat and lean.

Acceptance of Lamb Grades by the Industry

Despite recent opposition to, and the resulting changes in the lamb grading standards, the standards have been well accepted by the industry through the years, as evidenced by the fact that 45 percent of all the lambs slaughtered in the United States since 1940 were Federally graded. Table 1 shows a breakdown by years of the tons of lamb slaughtered under Federal inspection, tons graded and percent graded for each year. During the war years the Office of Price Administration required that all the lambs slaughtered commercially in the United States be graded. It will be noted that Tons Slaughtered, includes lamb and mutton only, whereas the figures for Tons Graded also include yearling mutton; therefore the percentages are relative values and do not represent the actual percent graded.

Present Lamb Grading Standards

Presently the standards consist of five grades; Prime, Choice, Good, Utility, and Cull. For research purposes carcasses are commonly graded to the nearest one-third of a grade and designated as high, average or low. According to U.S.D.A. (1960), carcasses are graded on a composite evaluation of two general grade factors, conformation and quality. These factors are concerned with the proportions of the various wholesale cuts and the proportions of meat and bone in the carcass and the quality of the lean respectively. Conformation is defined as the manner of formation of the carcass with particular reference to the relative development of the muscular and skeletal systems, it is also influenced to some extent by the quantity

Table 1. Tons of lamb and mutton slaughtered, tons graded, and percent graded from 1940-1960 (U.S.D.A., 1958).

Year	Lamb and mutton slaughtered (dressed weight in tons)	Lamb, yearling mutton, and mutton graded (dressed weight in tons)	Lamb graded (%)
1940	438,000	12,382.5	2.82
1941	461,500	16,093.0	3.48
1942	521,000	39,051.0	7.49
1943	552,000	495,386.0	89.74
1944	512,000	533,240.0	104.14
1945	527,000	512,145.0	97.69
1946	484,000	416,904.0	86.03
1947	399,500	104,435.0	26.14
1948	373,500	73,293.0	19.59
1949	301,500	53,816.5	17.84
1950	298,500	55,220.5	18.49
1951	260,500	182,677.5	70.12
1952	324,000	283,681.0	87.55
1953	364,500	122,566.0	33.60
1954	367,000	125,064.5	34.18
1955	379,000	121,341.5	32.00
1956	370,000	116,668.5	31.50
1957	353,500	129,160.0	36.70
1958	344,000	121,049.5	35.19
1959	369,000	128,692.0	34.87
1960	384,000	141,055.0	36.73
TOTAL	8,383,500	3,783,922.0	45.13 Av.

and distribution of external finish.

Quality of the lean flesh is best evaluated from consideration of its texture, firmness and marbling, as observed in the cut surface, in relation to the apparent maturity of the animal from which the carcass was produced. It is pointed out in the standards that in grading lamb carcasses direct observation of these characteristics is not possible. Therefore the quality of lean is evaluated indirectly by giving equal consideration to the quantity of fat intermingled with the lean between the ribs, called feathering; the streaking within and upon the inside flank muscles; and the firmness of fat and lean - all in relation to the apparent evidence of maturity.

Lamb Quality Research

Research on the quality of ovine meat has been very limited. There has been almost no work on the relationship of grade and the factors used in determining grade to quality evaluation in lamb meat, and very little work on the relationship of subjective and objective measurements of quality in lamb.

Less interest has been shown in meat quality in the ovine than in other species. This is understandable since sheep were originally kept for wool and milk instead of meat. According to Palsson (1939), wool was the most important product of English agriculture in the Middle Ages, and is an important source of income from sheep production in the United

States today, although today it is secondary to meat production.

Many problems are encountered by the researcher who wishes to evaluate meat quality. Watt (1951) points out that one of the greatest stumbling blocks is "human error", because in the last analysis meat quality can only be evaluated by the palate. He defines meat quality factors as the attributes possessed by meat that manifest themselves in such a way that they can be interpreted as desirable or not by the senses of taste, smell and sight. What is pleasing to one person may not be pleasing to another, this makes unbiased evaluation of meat quality difficult. A purely objective test is needed to measure or evaluate such factors as flavor, aroma, tenderness, juiciness, texture and color. It is unlikely that such tests will be devised for all these factors so the next best thing is to correlate objective testing with subjective evaluations.

There is some confusion in the literature regarding definition of the terms subjective and objective. Some use "subjective" to refer only to consumer preference tests while others use it to include all tests that depend on sensory reaction. "Objective" is used by some to refer to chemical, physical and similar measurements and exclude any tests dependent primarily on the sensory reactions of individuals. Boggs and Hanson (1949) use "subjective" to designate tests that measure the preference of individuals and "objective" to designate tests that measure differences in samples, whether measured by human senses or by other means. In this paper "subjective" will refer to tests depending on sensory evaluations or involving judgment by an individual and "objective" will refer to the chemical and physical tests and measurements. The present grading standards depend almost entirely upon subjective evaluations of the various quality factors.

Some of the first research done in the area of lamb quality was by Palsson (1939) in England. He observed at that time that a trend was beginning toward lighter weight lambs. He attributed this to less demand for fat due to mechanization. He also observed that age affects texture and flavor of meat, with older animals possessing coarser textured, darker colored, and stronger flavored lean than young animals. He noted that younger animals have a higher proportion of bone to edible meat.

Recently Batcher et al. (1962) have reported on the quality of raw and cooked lamb meat as related to fatness and age of the animal. They found more intramuscular fat in the rib-loins and legs of 11 to 14 month lambs than in 4-5 month old lambs. They noted a decrease in tenderness in the rib-loin cut, as age of the animal increased. Percent lean cuts decreased with age while percent separable fat increased. Juiciness and flavor of either the rib-loin or leg cut were not consistently associated with the age of the animal, however, panel scores indicated that lamb meat became less tender as age of animal increased. The amount of separable fat and intramuscular fat did not affect tenderness, juiciness or flavor of the cooked meat.

A number of workers have been concerned with the importance of fatness to the quality of lamb meat. In a study involving 924 lambs Hankins and Ellis (1939) found no significant correlation between tenderness and fatness in lambs when they used percent caul fat and percent kidney fat as indicators of fatness.

In an experiment using limited fed lambs versus full fed lambs, Cover et al. (1944) found that in some pairs full fed lambs were more tender, but in others the limited fed one was more tender. They concluded that it is doubtful that fatness influences tenderness in lamb to any marked degree. Weber et al. (1931) also compared limited feeding to full feeding in lambs and found very little difference in tenderness between lots, but continued full feeding increased the desirability of meat aroma and there was a fairly consistent trend of improvement in lean flavor with full feeding. Quantity and quality of the juice increased as the feeding period progressed. Gaddis et al. (1950) in a study using 115 lambs found no relationship between fat in the press fluids and palatability factors.

The effect of degree of finish of the animal on the flavor of meat was studied by Howe and Barbella (1937). They observed that certain inherent flavors in the fat of meat are characteristic of species, and become evident when the fat is heated. Fats contribute body richness and smoothness to meat juices or gravies which although chiefly mechanical in effect, have much to do with desirability of meat. Barbella *et al*. (1936) found that retarding growth in lambs made the meat less desirable in flavor and less tender. The *longissimus dorsi* muscle from lambs retarded in growth contained less protein and fat and more water. Also the ratio of water to protein was higher.

Barbella *et al*. (1939) reported a highly significant effect of fatness on the desirability of the flavor of lean in beef, and Branaman *et al*. (1936) reported that scores on intensity and desirability of flavor of lean showed general progressive improvement associated with increase in fatness.

Hofstrand and Jacobson (1960) attempted to determine the role of fat in the flavor of lamb and mutton by using mutton broths of varying fat content, and treated samples of lamb depot fat, which were submitted to a taste panel as a series of paired comparisons. They concluded that the amount or absence of fat did not significantly affect the taste of the broths, however, there was some indication that fat may contribute to the aroma of lamb and mutton broths. When expressed fat was compared with treated fats, depot fats were found to have flavor components. These flavor components were easily volatilized and changed by heat, were soluble in cold water and partially removed by activated carbon. The characteristic lamb flavor may be quite volatile so we cannot rule out the importance of volatile flavor components in fats.

Several sensory methods were used by Jacobson et al. (1962) to study lamb flavors. The typical flavor of cooked lamb was primarily an aroma. The aroma and taste could be described by the terms "fragrant", "oily", "sweet", and somewhat "musty". The "musty" character was the definitive difference between lamb and other meats. By comparing lamb volatiles and cooked lamb meat with odors of dilute chemicals, the presence of compounds with odors similar to ethyl oleate, diacetyl, and sulfur compounds was indicated. In another part of the study they found that individual animal variation affected flavor more than differences in sex of the animal or extreme differences in age.

Crocker (1948) also studied lamb flavor, and observed lamb was a far more alkaline meat (pH 7) than beef or pork. It had a marked hexylamine character even when strictly fresh and there was also present a strongly caprylic or pelargonic acid type of odor typical of sheep and goats. At no time was any sulfury odor conspicuous with lamb.

At the present time, there has been no report of the isolation and identification of the specific flavor components in lamb.

Although the effect of breeding on quality has not been included in this study, Wilcox and Galloway (1952) used three different Rambouillet and Columbia crosses and found a significant difference in tenderness as measured by shear force values due to breed difference. However panel scores for tenderness, texture, flavor of lean and of fat, and juiciness were similar for the various crosses.

The relationship between marbling score and various lamb carcass characteristics were determined by Stouffer et al. (1958). The correlations were .577 with dressing percent, .715 with carcass grade, .493 with external fat thickness and -.252 with shear force value. All of the correlations were significant except that of marbling score with shear force value. The following average values were reported for the 34 lambs used in this study. Average dressing percent, average fat thickness, average marbling score, and average shear value were, respectively, for Prime, 55.0, 0.29, 10.5 and 8.5; for Choice, 52.2, 0.28, 9.4 and 7.6; for Good, 50.6, 0.15, 7.8 and 9.9; and for Utility, 47.4, 0.12, 5.5 and 12.3.

Texture, a factor that has been used extensively as a meat quality indicator, was found by Clauss (1954) to have little relationship to the qualities of meat that determine consumer acceptance or to any other quality by which meat is customarily compared. However, in a consumer preference study Levine and Hunter (1956), found that the texture of lamb was an objectionable characteristic to some homemakers. They described it as "tough", "grisly", "fat", or "greasy". They also found that 2 in 10 homemakers objected to the unpleasant flavor of lamb.

Lamb Carcass Cutability

Carcass cut out or cutability and the various methods of predicting cutability have been reported by several workers. Since approximately 50 percent of the emphasis in grading lambs is concerned with conformation or the proportionate quantity of lean, fat, and bone in the carcass, a few of these articles will be reviewed here.

Hammond and Appleton (1932) observed that the fat content in the shoulder was the best indicator of fat in the entire carcass with the leg being second best. Generally the leg contained a smaller percent fat than the rest of the carcass. They also observed that the proportion of lean to bone increases with age and that early maturing breeds have a higher proportion of muscle to bone than later maturing breeds. Palsson (1939) also reported a high correlation between the weight of all constituents of the leg and the same constituents of the total carcass. He observed that length of cannon bone is highly correlated with weight of bone and that the weight of the four cannon bones was highly correlated with skeletal weight.

Hankins (1947) found that the rib cut was the best indicator of fat, lean and bone in the carcass; the correlations with each of these constituents being over 0.90.

Barton and Kirton (1958) found that physically separable fatty tissue is highly correlated with carcass weight, especially more so than is muscular tissue in mature sheep.

In lambs the correlations are approximately equal for fat and muscle tissue. This suggests that mature sheep lay down fatty tissue approximately twice as rapidly as muscular tissue with increasing weight, but in lamb carcasses these tissues are laid down at about an equal rate.

Loin eye area has been used extensively as an indicator of muscling in other species. In a study of carcass measurements taken on 114 lambs Botkin et al. (1959) found that loin eye area was not as good a measurement of meatiness in lamb as was leg area. In a physical separation of 30 carcasses into lean, fat and bone there was an indication that area of loin eye and of leg area combined is a reliable measure of lean meat content.

Live weight taken shortly before slaughter appears to be approximately as accurate for predicting loin eye area as any carcass measurements which do not require cutting the carcass according to Bailey et al. (1961). With 347 crossbred lambs they found a low correlation between loin eye area and carcass grade.

Knight et al. (1959) determined percent fat in the 12th rib cut and found that percent loin and rack were positively correlated to it, with correlation coefficients of .35 and .42 respectively, and percent leg was negatively correlated with it. They also found a correlation of 0.47 between percent lean and bone in the carcass.

Muscle Tissue Color

Color is generally considered along with marbling, texture, feathering and fat streaking as a meat quality factor. In lamb grading it has added importance as one of the more important factors used in determining the maturity of the carcass. Typical lamb carcasses have a light red color, yearling mutton carcasses are slightly dark red and mutton carcasses have a dark red color of lean, according to U.S.D.A. (1960). The official standards for lamb grades specify, "In determining the maturity class of ovine carcasses, more consideration is given to characteristics of the flesh than is given to the characteristics of the skeleton".

Color of muscle tissue can be influenced by many factors, of which age is only one. Myoglobin, or muscle hemoglobin as it is sometimes called, is the pigment responsible for coloration of muscle tissues. Millikan (1939) obtained it in a crystalline form and found that it is a true hemoglobin but differs from blood hemoglobin in that it contains only one iron atom per molecule. It has a very high oxygen affinity and it has a lower affinity for carbon monoxide relative to oxygen. Myoglobin acts as a short time oxygen store, tiding the muscle over from one contraction to the next. He also found that myoglobin concentration increases with age and activity of the muscle.

According to a review by Hedrick <u>et al</u>. (1959), several other workers have also reported that with increasing age of the animal the color of the muscle darkens. Lawrie (1950) found that the relationship of myoglobin concentration with age is significant at the .01 level. He demonstrated that activity is the fundamental factor controlling the amount of pigment found in any muscle by comparative analysis of muscle from the draft horse, the hunter, and the thoroughbred; by analysis of wing and leg muscles in domestic fowl and pigeon; and by estimations carried out on muscles in normally active and immobile pigs.

Lawrie (1953) concluded that an increased myoglobin content represents one of the responses of muscle tissue to the influence of enforced activity, provided it continues over an extended period as in training. Over a short period even the most severe exercise elicits no such response, however, it diminishes the glycogen reserves in the muscle. This influences the pH of muscle tissue which is another factor involved in tissue color. When glycogen reserves are depleted in the tissue prior to slaughter there will be little or no lactic acid produced in the tissue after slaughter to give a low pH, therefore animals which have depleted glycogen reserves will produce carcasses with a high pH of the muscle tissues.

Hall *et al*. (1944) found that high pH, low glucose level, practically no glycogen, high inorganic phosphate, low oxidation potential, and rapid oxygen uptake were characteristics of dark cutting beef muscle tissue. The most significant difference in properties of dark beef and bright beef appeared to be lower amounts of lactic acid in the dark beef.

Mackintosh and Hall (1935) observed that normal beef brightens materially when a fresh cut surface is exposed to the air. The process is very rapid for 30 minutes, and continues at a decreased rate for 3 hours or more. They defined dark cutting beef as that in which color fails to brighten normally or brightens at a much slower rate, and black cutters are those in which color does not brighten at all, and the cut surface is gummy and sticky to the touch. They were able to produce dark cutters only by delayed bleeding.

Hedrick (1960) reported that dark cutting beef has an abnormally high pH, low glycogen content, and a sticky gummy texture. At pH 5.4 the color of beef muscle is bright cherry red, at pH 5.8 the color is "shady" or dark red and at 6.2 to 6.8 it is purplish black.

The formation of the bright color in muscle tissue is apparently due to the conversion of myoglobin to oxymyoglobin. Lawrie (1958) found that the depth of the layer of oxymyoglobin on the surface of meat is determined by the rate of diffusion of oxygen inwards from the atmosphere and by the rate of oxygen utilization of the tissue enzyme systems. These processes are determined by a number of factors. If the rate of oxygen utilization increases while the rate of diffusion inwards remains constant the depth of the oxymyoglobin layer will diminish. Cytochrome oxidase, the principle enzyme responsible for oxygen uptake in biological tissues, increases rate of oxygen uptake at an abnormally high pH. Also Urbin and Wilson (1960) have reported that the uptake of oxygen in bovine tissue by succinic dehydrogenase is increased at a higher pH. Either one or both of these could contribute to dark color by reducing the depth of the oxymyoglobin layer on the surface until the purplish color of reduced myoglobin predominates.

Lawrie (1958) also suggested that the structure of tissues having a high pH might be altered since the isoelectric point of the principle muscle protein, actomyosin, is at pH 5.6, at higher pH values the protein binds more water and this will diminish the free fluid phase of the muscle. This causes swelling of the muscle fibers giving the muscle a closer structure. This could lower the rate of oxygen diffusion to the intracellular proteins and thus impose an additional limit on oxymyoglobin formation at the surface. Bate-Smith (1948) suggested that tissue with a high pH, because of its close structure, will absorb incident light and appear darker than normal tissue in which the fibers have shrunk apart and will scatter incident light making it appear lighter.

Lawrie (1958) points out that in dark cutting beef there is no unusual pigment, and usually no greater than normal amount of residual blood, and that myoglobin concentration of dark cutting beef is within the normal range.

Numerous factors affect the ultimate pH of muscle.

Exhaustive exercise prior to slaughter will reduce the amount of glycogen available for the formation of lactic acid thus contributing to a high ultimate pH. Hedrick (1959) pointed out, however, that in beef cattle it is difficult to deplete muscle glycogen by enforced exercise alone.

Briskey et al. (1959b) subjected fasted and full fed hogs to a single severe exercise stress and found that muscles became dark in color, high in pH value and dry in appearance. Both treatments significantly decreased initial muscle glycogen. The increase in intensity of muscle color was not solely due to increased pigment quantities but was more likely due to a change in muscle consistency as a result of its higher pH.

Briskey et al. (1959c) studied the effect of basal and high sucrose regimens on hogs subjected to exhaustive exercise prior to slaughter. They found exhaustive exercise of the hogs on the basal ration produced dark firm muscles that were dry in appearance and high in pH. In contrast hogs fed a high sucrose ration and given no exercise had muscles that were pale in color, soft in texture and extremely watery in appearance with a relatively low pH. When the sucrose fed hogs were exercised they presented muscles which closely resembled the control of basal ration and unexercised.

The pig seems to be much more susceptible to glycogen depletion by activity immediately pre-slaughter than cattle. It is difficult to deplete the muscle glycogen of cattle by enforced exercise alone.

Activity and struggle immediately preceding death can cause the breakdown of considerable quantities of glycogen. Bate-Smith and Bendall (1949) controlled this by injection of myanesin which caused complete muscle relaxation and abolished the death struggle. They found conservation of glycogen by this means did not affect the ultimate pH of the psoas major muscle in a rabbit. They also observed that glycogen reserve could be varied by injection of insulin in convulsant dosage, which leads to the extreme complete exhaustion of muscle glycogen. Reducing the intake of food also was found to affect glycogen level.

Lawrie (1958), however, was unable to affect the ultimate pH in cattle after fasting for periods up to 28 days. Then he used a combination of the stress of fasting and enforced exercise and found that neither fasting, enforced exercise nor a combination of both under natural conditions will bring about a marked raising of the ultimate pH. It is apparent that ruminants have a unusually high capacity to gain energy by oxidation of fatty metabolites thus tending to spare carbohydrate under conditions of stress which would deplete glycogen reserves in the non-ruminant animal.

Selye (1936), working with rats, found that if the organism was severely damaged by acute non-specific nocuous agents as exposure to cold, excessive muscular exercise, or intoxication with sub-lethal doses of diverse drugs, such as adrenalin; a stress syndrome appeared. The symptoms of this syndrome are independent of the nature of the damaging agent, and represents a response to damage as such. According to Hedrick (1960) the central nervous system and the muscles of cattle require glucose and short chain fatty acids as energy sources. In stress the sympathetic nerve center located in the back part of the hypothalamus is aroused, then nerve impulses are carried to the vascular system and the organs involved in metabolism. The adrenal medulla is stimulated and causes a discharge of adrenalin or nor-adrenalin.

Cori (1940) has shown that epinephrine or adrenalin accelerates the conversion of glycogen to lactic acid in muscle and conversion of glycogen to glucose in the liver. It apparently acts by increasing the phosphorylase activity in the cell thereby increasing the concentration of the active enzyme.

When glycogen stores are diminished due to increased secretion of adrenalin, according to Hedrick (1960), corrective physiological mechanisms are stimulated. The anterior pituitary is stimulated to produce adrenocorticotrophin (ACTH) which in turn augments adrenal glucocorticoid secretion. The glucocorticoids accelerate the formation of glycogen from the protein stores in the body, however, muscle glycogen can be depleted much faster than it can be replenished to normal levels.

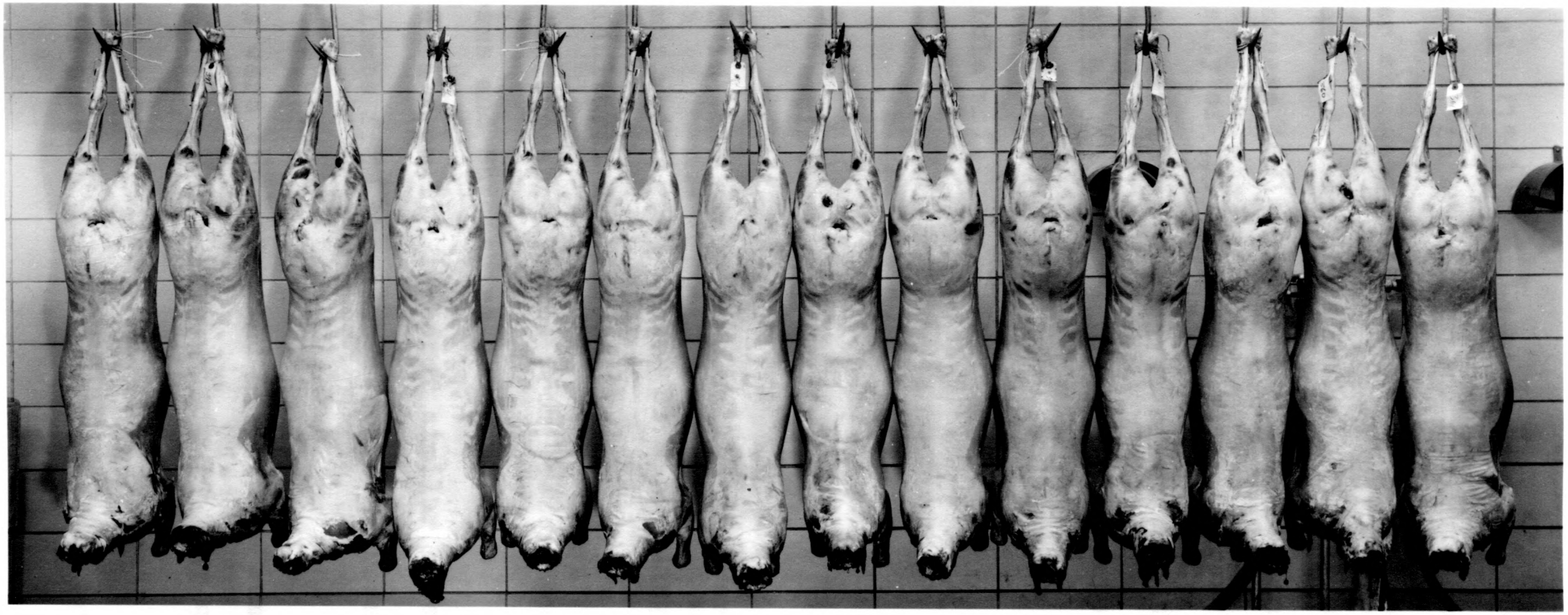
Hedrick *et al*. (1959) administered adrenalin subcutaneously in beef cattle and produced hyperglycemia and glycosuria. When it was administered approximately 24 hours prior to slaughter at the rate of 3 milligrams per 100 pounds of body weight, dark cutting beef carcasses were produced. As the level of adrenalin was increased the color of the carcass muscles became darker, the muscle pH was higher, and the texture of the muscle more sticky and gummy. Carcasses from cattle injected with adrenalin at periods from 24 to 96 hours showed improvement in color as time increased between treatment and slaughter. However these carcasses were not as light and bright in color as the controls, even when 96 hours elapsed between time of injection and slaughter. When dark and bright beef was subjected to a taste panel evaluation no significant difference in eating qualities was detected.

Sixty-four lambs were used to determine the effect of pre-slaughter adrenalin injections on subsequent carcass characteristics by Hedrick _et al_. (1961). Flank muscles from adrenalin treated lambs were significantly darker in color and higher in pH than those from untreated animals. Color scores and pH values of the flank muscles were related to the pH values of the _longissimus dorsi_ muscle. Color in the flank muscles was not related to myoglobin content. There was a significant inverse relationship between myoglobin content of the _rectus abdominus_ muscle and pH of the _rectus abdominus_. The increase in color intensity of lamb muscle was influenced more by changes in muscle consistency due to high pH than by quantity of pigment.

EXPLANATION OF PLATE I

A representative sample of the lamb carcasses used in this study.

PLATE I



Sayre *et al*. (1961) placed hogs in cold water (0.5°C) for 30 - 40 minutes, in an attempt to simulate the stress of a severe weather change. This change from warm to cold temperature decreased the initial muscle glycogen level with a resultant decrease in lactic acid concentration and increase in color intensity of the muscle tissues. Water binding capacity of the chilled muscle was not consistently affected.

Briskey *et al*. (1960) and Topel (1962) reported that there are muscle differences in color, myoglobin concentration, pH and expressible moisture.

EXPERIMENTAL METHODS

History of the Animals

Data used in this study were collected over a three year period from lambs which were a part of a breeding experiment at the Kansas Agricultural Experiment Station. The first years data came from 87 crossbred lambs from Western ewes and sired by Hampshire rams and Shropshire clean up rams. The second year included data from 115 lambs of similar breeding. The third year 77 lambs from the same ewe flock crossed with Suffolk rams were used.

All lambs were creep fed and allowed to run with their dams until they reached the slaughter weight of 90 pounds. The creep ration consisted of; Milo, 50 percent; Dehydrated alfalfa meal (17 percent protein), 45 percent; Molasses, 5 percent; and Aurofac 10, 1000 mg. per 100 pounds.

After being held off feed for 12 hours all lambs were slaughtered at the University Meat Lab, using conventional slaughter procedures.

Collection of Data

Data collected at the time of slaughter included; slaughter weight, pelt weight, caul fat weight, and the weight of the stomach and intestines plus the contents of the alimentary tract.

The carcasses were chilled for 48 hours, after which the chilled carcass weight was determined. The carcasses were graded to the nearest one-third grade by a representative of the federal grading service. In addition to grade the subjective indices of quality in the carcass which are considered in grading were scored by the grader using a scale from 1 to 11 as outlined in Table 2. A score of 11 represented the highest degree of development of a characteristic while a score of 1 represented the lowest degree of development or a lack of the characteristic.

The carcasses were ribbed between the twelfth and thirteenth rib and the actual marbling score and color of lean in the *longissimus dorsi* muscle were determined by the grader. The *longissimus dorsi* muscles were traced, and fat thickness over the rib eye was included on the tracing. Later the area of the *longissimus dorsi* was measured from the tracings

Table 2. Scoring system for carcass quality indices.

Characteristic	Degree of Development 11	10	9	8	7	6	5	4	3	2	1
Conformation	Very Blocky	Blocky	Mod. Blocky	Sli. Blocky	Sli. Rangy	Mod. Rangy	Rangy	Very Rangy			
Quantity of External Finish	Very Thick	Thick	Mod. Thick	Sli. Thick	Sli. Thin	Mod. Thin	Thin	Very Thin	Extra Thin	Practically Devoid	Devoid
Color of Lean (Flank steak)	Light Pink	Sli.Dark Pink	Dark Pink	Light Red	Sli.Dark Red	Dark Red	Very Dark Red	Ext. Dark Red			
Color of Lean (*Longissimus dorsi*)	"	"	"	"	"	"	"	"			
Feathering	Very Abundant	Abundant	Mod. Abundant	Sli. Abundant	Moderate	Modest	Small	Slight	Traces	Practically Devoid	Devoid
Overflow Fat	"	"	"	"	"	"	"	"	"	"	"
Fat Streakings (Flank steak)	"	"	"	"	"	"	"	"	"	"	"
Fat Streakings (other Flank muscles)	"	"	"	"	"	"	"	"	"	"	"
Kidney and Pelvic Fat	"	"	"	"	"	"	"	"	"	"	"
Estimated Marbling	"	"	"	"	"	"	"	"	"	"	"
Actual Marbling	"	"	"	"	"	"	"	"	"	"	"

EXPLANATION OF PLATE II

Fig. 1. Illustrates a slight amount of feathering between the ribs. This is the smallest amount observed in carcasses of this study.

Fig. 2. Illustrates a moderately abundant amount of feathering between the ribs. This is the largest amount observed in carcasses of this study.

PLATE II

Fig. 1

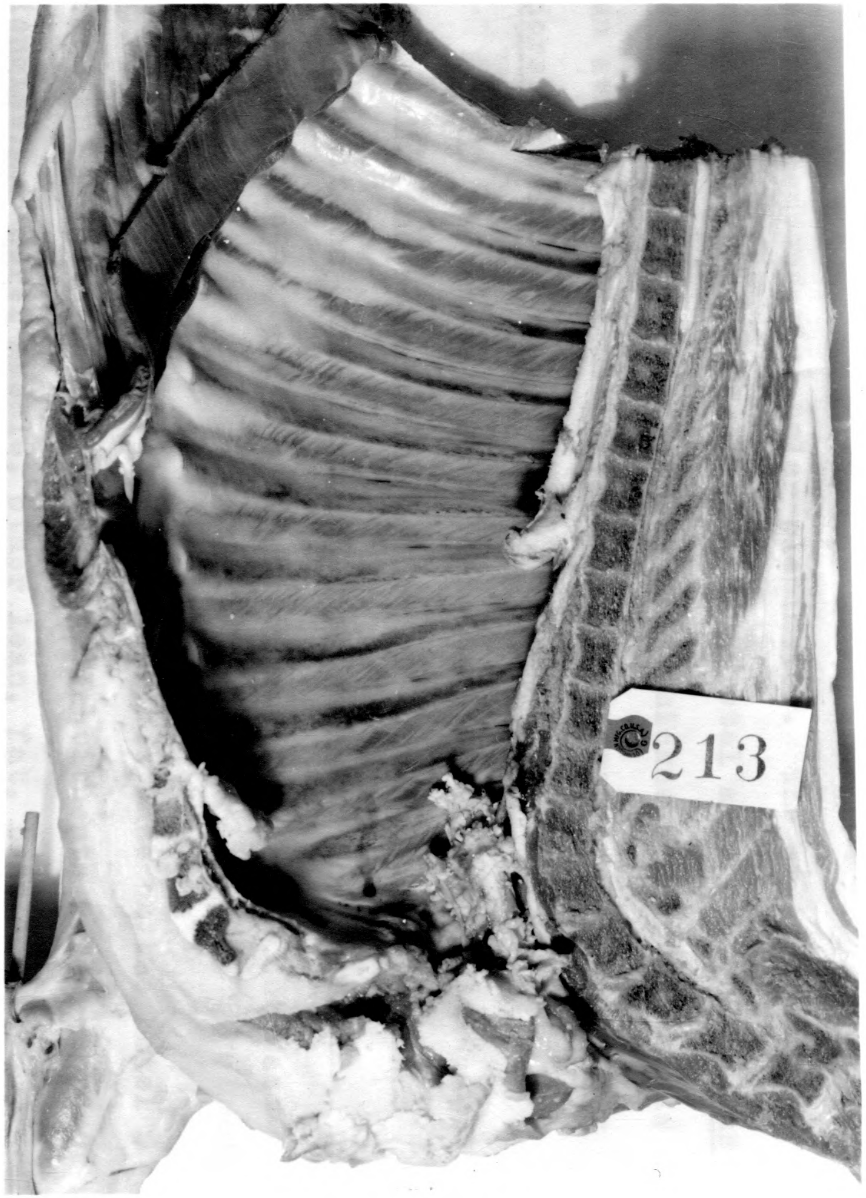


Fig. 2

using a compensating polar planimeter. The areas for both muscles were added together giving total area of longissimus dorsi muscle for the carcass. Fat thickness is reported as an average of six measurements, three over each longissimus dorsi muscle.

All carcasses were broken down into the wholesale cuts following the recommended method of cutting lamb carcasses adopted at the Sixth Annual Reciprocal Meat Conference, Galloway (1953), and the weight of each wholesale cut was recorded.

A complete physical separation was made on the hotel rack and weights of the following constituents were recorded; longissimus dorsi muscle, other lean, fat, bone, overflow, and intercostal muscle. The hotel rack was used for the physical separation because it has been reported by Hankins (1947) that its composition is the best objective index of total carcass composition.

The loins were split and the right or left side from alternate animals was sent to the Food and Nutrition Department in the School of Home Economics for organoleptic determinations.

Immediately after breaking the carcasses, samples were taken from the longissimus dorsi muscle at the twelfth rib and from the rectus abdominis muscle for color intensity determination with a Photovolt Reflectance Colorimeter. Results are reported as percent reflectance.

The longissimus dorsi muscles and the intercostal muscles from both sides of the rack were each ground three times through an Oster food grinder. Samples were taken from this ground tissue and stored frozen for subsequent analysis for fat content.

Chemical Determination of Fat

The Modified Baboock Method for Determining Fat in Meat Products, as reported by Kelley _et al._ (1954) was used for fat determination in the _longissimus dorsi_ and intercostal samples. Hall (1960) further outlines the procedure in detail as follows; Nine gram samples of _longissimus dorsi_ muscle or 4.5 gram samples of intercostal tissue were used. Each sample was placed in a 100 ml. beaker, 10 ml. of water was added and well dispersed with a stirring rod. Five ml. glacial acetic acid was added with stirring to break up any lumps. Then 10 ml. of concentrated sulfuric acid was added slowly with stirring until all lumps dissolved. Next the hot solution was transferred to a Babcock milk flask in the case of the _longissimus dorsi_ sample and a Babcock cream flask in the case of the intercostal muscle. The beaker was rinsed with a small amount of hot water and the washings were added to the Babcock flasks. Five more milliliters of concentrated sulfuric acid were added to the flasks, mixed and then centrifuged for 5 minutes at 1,000 R.P.M. After centrifuging, hot water was added until the fat layer floated to the score region of the Babcock flask. Then the flask was placed in a 70°C water bath for 2 minutes, after which it was centrifuged again for 3 minutes, then reimmersed in the water bath for 2 minutes. The fat column was read with calipers from the bottom of the upper meniscus to the bottom of the lower meniscus.

Calculations of percent fat in the samples:

Babcock milk flask,

$$\text{Percent fat} = \text{scale reading} \times \frac{18}{\text{weight of sample}}$$

Babcock cream flask,

$$\text{Percent fat} = \text{scale reading} \times \frac{9}{\text{weight of sample}}$$

Percent fat in the longissimus dorsi and intercostal muscles was used as objective indices for marbling and feathering respectively. Overflow fat was determined objectively by weighing overflow fat disected from the hotel rack.

Lamb Color

The second phase of this study was designed to determine the effect of pre-slaughter treatment on some physical and chemical characteristics of lamb with particular interest in the color of muscle tissue.

Thirty-two crossbred lambs were used in this phase. The lambs were randomly alloted to four treatments within 48 hours after birth. They were creep fed while nursing their dams until they reached the slaughter weight of 90 pounds.

Lot I, the control, was fed the creep ration described earlier. The animals in Lot II, received a ration high in iron, 700 mg. iron sulfate and 70 mg. of copper sulfate were added per pound of creep ration. The adrenalin treated lambs in Lot III received the control ration. At slaughter this lot was subdivided into two groups. Group (A) received a 5 cc injection of a 1:1,000 solution of epinephrine hydrochloride in physiological saline at 12 and again 2 hours prior to slaughter. Group (B) received a 10 cc injection of a 1:1,000 solution of epinephrine hydrochloride at 12 and again at 2 hours prior to slaughter. Lot IV received the control ration, this lot was also subdivided into two groups of four lambs each. Group (A) consisted of four lambs exercised to near exhaustion on a treadmill immediately prior to slaughter. Group (B) consisted of four lambs exercised to near exhaustion with a sheep dog prior to slaughter.

The animals were slaughtered, chilled, graded and cut into wholesale cuts by the procedures already described. All of the information collected on lambs in the first phase of this study was also collected on these lambs. In addition, pH and myoglobin concentration were determined on the longissimus dorsi, rectus abdominus and intercostal muscles. Expressible moisture was also determined for the longissimus dorsi muscle.

Determination of Hydrogen Ion Concentration

pH determination on the muscles described was made with a Beckman Zeromatic pH meter immediately after the carcasses were cut, or approximately 48 hours after slaughter. Electrodes were inserted or probed in the cut surface of the muscle without addition of water.

Myoglobin Determination

Myoglobin was determined by the method which Hall (1961) adopted from the Poel-Cyano method (Poel, 1949). Following is the procedure used:

1. Weigh duplicate 10 gram samples.
2. Process for 2 minutes in a Waring Blendor with 42.5 ml. of cold 0.06 Molar phosphate (pH 5.0) and X ml. of 0.1 Normal sulfuric acid. (X = (pH - 5) x 0.35).
3. Centrifuge 20 minutes at 3,000 R.P.M. in 50 ml. polyethylene tubes.
4. Decant into 50 ml. tubes and heat slowly in a water bath to 54°C. while stirring with the thermometer.
5. Cool rapidly in an ice bath to about 25°C.
6. Transfer to 100 ml. beakers and adjust the pH to 7.1 - 7.2 with solid Na_2CO_3.
7. Return to same tubes used in 4, and centrifuge 10 minutes at 2,500 R.P.M. Decant through filters.
8. Oxidize with 2 or 3 pin head size crystals of $K_3Fe(CN)_6$ in a 50 ml. Erlenmeyer flask.
9. Form a Myoglobin cyanide complex by adding a small crystal of KCN.
10. Transfer to the spectrophotometer cell. Read at 540 mμ. Record the optical density. Mg. myoglobin per gram of tissue equals OD x 7.50.

Spectrophotometer readings were determined with a Bausch and Lomb Spectronic 20 spectrophotometer. Optical densities were read at 540 mμ wave length.

Expressible Moisture Determination

Expressible moisture was determined by the method of Grau and Hamm (1953) as modified by Briskey et al. (1959a). A 300 mg. sample of muscle tissue was weighed accurately and placed in the center of a 12.5 cm. diameter Whatman No. 1 filter paper. The filter paper was then placed between two plexiglass plates. These were placed in a Carver press and 10,000 pounds per square inch pressure applied for 5 minutes. Two distinct rings were formed on the filter paper. The inner ring was pressed muscle tissue and the outer ring represented moisture expressed from the tissue. The areas of the two circles were measured with a polar planimeter. Expressible moisture is reported as a ratio of moisture area to muscle area.

Statistical Analysis

The analysis of all data was done by the Statistical Laboratory of the Kansas Experiment Station. Simple correlation coefficients were calculated between all possible combinations of the factors studied. Multiple correlations were calculated for some factors.

An analysis of variance was used on the color study. If a significant variance ratio was calculated for a certain characteristic, Duncan's Multiple Range test as modified by Kramer (1956) was used to determine where treatment differences existed.

Data from each year of the study were analyzed separately. Pooled correlations were not calculated, therefore, three r values will be reported for each relationship. In each case they will be listed consecutively by years, 1960, 1961, and 1962 respectively.

Levels of significance were determined according to the method outlined by Snedecor (1956), they are; for the 1960 data at the .05 level r = .212; and at the .01 level r = .277 with 86 degrees of freedom; for the 1961 data at the .05 level r = .182 and at the .01 level r = .238 with 113 degrees of freedom; and for the 1962 data at the .05 level r = .224 and at the .01 level r = .292 with 75 degrees of freedom.

RESULTS AND DISCUSSION

Factors Influencing U.S.D.A. Grade

Feathering was observed to account for between 40 percent and 50 percent of the variation in carcass grade. The correlation coefficients between feathering and carcass grade (.765**, .698**, and .640**) were higher than for any other factor which was correlated with grade.

Conformation seems to be the next most important factor in determining carcass grade in lambs. Correlations of conformation with grade (.441**, .636** and .554**) were all highly significant. Other factors correlated with grade were

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* $(P < .05)$
** $(P < .01)$

fat streakings in the flank steak (.452**, .355** and .557**); fat streaking in the other flank muscles (.460**, .383** and .374**); quantity of external finish (.191, .453** and .559**); color of lean in the flank steak (.396**, .182 and .327**); overflow fat (.133, .316** and .188); and kidney and pelvic fat (-.020, .347** and .495**). Correlation coefficients of grade with some of the objective determinations of the above factors are included in Table 3.

In the multiple correlations, which were determined for the 1960 and 1961 data, it was observed that when all the factors which are important in determining grade were combined, in the 1960 data the combined correlation (.786**) was not much higher than the correlation of feathering alone with grade (.765**). In the 1961 data the combined correlation was .829** which was considerable higher than with feathering alone (.698**).

Carcass Grade and Marbling

Marbling was estimated by the grader before the carcasses were ribbed, and the actual marbling score was determined after ribbing. Percent fat in the longissimus dorsi muscle at the twelfth rib was also determined. Correlation coefficients between grade and estimated marbling (.770**, .677** and .703**) and between feathering and estimated marbling (.812**, .794** and .708**) were high, indicating that the grader used these two indices of quality in the carcass in his estimation of marbling. The correlation coefficients of estimated marbling

Table 3. Correlation coefficients between U.S.D.A. carcass grade and other factors studied.

Variables	Correlation Coefficients 1960	1961	1962
U.S.D.A. Carcass Grade vs.			
Feathering	.765**	.698**	.640**
Conformation score	.441**	.636**	.554**
Fat streakings in flank steak	.452**	.355**	.557**
Fat streakings in the other flank muscles	.460**	.383**	.374**
Quantity of external finish	.191	.453**	.559**
Overflow fat score	.133	.316**	.188
Overflow fat weight	.454**	.354**	.220
Kidney and pelvic fat	-.020	.347**	.495**
Weight of the kidney knob	.147	.339**	.345**
Color of lean in the flank steak	.396**	.182	.327**
Colorimeter reading, flank steak	---	.059	.175
Color score in the *longissimus dorsi* muscle	.492**	.162	.118
Colorimeter reading, *longissimus dorsi* muscle	---	.039	.089
Marbling	.363**	.371**	.199
Estimated marbling	.770**	.677**	.703**
Percent fat, *longissimus dorsi*	.290**	.325**	.238*
Percent fat, intercostal muscle	-.123	.352**	.584**
Cross-sectional area of the *longissimus dorsi* muscle	.243*	.086	-.025
Thickness of fat over the *longissimus dorsi* muscle	.236*	.249**	.332**
Chilled carcass weight	.137	.545**	.515**
Dressing percent	.313**	.426**	.467**
Flavor intensity	-.400**	-.070	-.173
Flavor desirability	.368**	.168	.103
Juiciness	.236*	.129	.319**
Initial tenderness	.256*	-.002	.162
Number of chews	.340**	.167	-.180
Final tenderness	.199	-.100	.195
Caul fat weight	.256*	.324**	.204
Percent fat in hotel rack	.233*	.439**	.613**
Weight fat in hotel rack	.195	.465**	.607**
Percent lean in hotel rack	-.017	-.319**	-.552**
Weight lean in hotel rack	.133	.157	-.044
Days of age	.435**	.060	.077

* (P < .05)
** (P < .01)

with actual marbling score (.296**, .357** and .313**) were all highly significant, and those between estimated marbling and percent fat in the longissimus dorsi muscle (.152, .371** and .367**) were highly significant in two years data.

Grade versus marbling showed correlations of .363**, .371** and .199, while grade and percent fat in the longissimus dorsi muscle showed values of .290**, .325** and .238*.

Correlations of these and other factors related to U.S.D.A. Carcass Grade are shown in Table 3.

U.S.D.A. Grade and Sensory Panel Scores

The relationship of carcass grade to quality of the meat in the carcass, as evaluated by a taste panel, is of particular interest in giving some indication of the value of carcass grade as an indicator of quality.

Considerable variation was noted between the different years in which data was collected, in the strength of relationship of carcass grade to the various sensory factors studied. In the 1960 data, higher correlation coefficients were observed between carcass grade and the sensory factors studied than in succeeding years.

A slightly stronger relationship was observed between carcass grade and juiciness than the other factors evaluated by the taste panel. The correlation coefficients (.236*, .129 and .319**) were significant in two years data.

Intensity of flavor tended to be negatively correlated with carcass grade (-.400**, -.070 and -.173), while desirability of flavor was positively correlated with carcass grade (.368**, .168, and .103). This suggests that flavor may be less intense and more desirable in the higher grades.

Tenderness was scored by the panel as follows: initially, on the first bite; then the number of chews was counted and recorded; after which a final tenderness evaluation was made based on the number of chews. The correlation coefficients between grade and initial tenderness (.256*, -.002, and .162), grade and number of chews (.340*, .167 and -.180), and grade and the final tenderness evaluation (.199, -.100 and .195) were too low and inconsistent to draw conclusions on the relationship of tenderness and grade.

Factors Related to Sensory Evaluations

Marbling or intramuscular fat seems to show the strongest relationships with the various sensory factors, although these relationships were not consistent from year to year. Juiciness, was correlated with marbling (.379**, .103 and .163), and percent fat in the longissimus dorsi muscle (.223*, .233* and .364**) indicating that marbling has a positive relationship with juiciness.

The three tenderness factors studied showed a fairly strong relationship with marbling the first year, but results were inconsistent in the other two years data. Correlation coefficients of initial tenderness with marbling were .375**,

.287** and .174; and with percent fat in the longissimus dorsi muscle were .154, .284** and .197. The number of chews recorded by panel members for each sample had correlation coefficients of -.415**, -.080 and -.202 with marbling, and -.208, -.205* and -.152 with percent fat in the longissimus dorsi muscle. Although these correlations were not consistently significant, they were consistently negative, indicating there may be a slight increase in tenderness with increased marbling. The correlations of marbling with the final tenderness scores (.344**, .108 and .268*), and percent fat in the longissimus dorsi muscle with final tenderness scores (.139, .126 and .272*) tend to bear out this relationship.

The correlation coefficients between marbling and intensity of flavor were -.217*, -.019 and -.180; and correlations between percent fat in the longissimus dorsi muscle and intensity of flavor were, -.139, -.049 and -.274*. When desirability of flavor was scored by the taste panel the correlation coefficients with marbling were .327**, .083, and .045; and with percent fat in the longissimus dorsi muscle .283**, .122 and .141. Although these correlations are rather low it can be noted that intensity of flavor was consistently negatively correlated with both the subjective and objective methods of determining intramuscular fat, while the desirability of flavor was consistently positively correlated with these determinations.

Since feathering was observed to be one of the most important factors related to grade it seemed desirable to determine the relationship of this characteristic to the sensory factors.

The correlation coefficient of feathering with juiciness (.232*) was significant only in the 1960 data. Percent fat in the intercostal muscle was significantly correlated with juiciness only in the 1962 data (.240*).

There were no significant correlations between feathering and any one of the three tenderness factors studied. Percent fat in the intercostal muscle was significantly correlated at the .05 level with initial tenderness in two years' data, (-.214*, .173 and .236*). The following correlations were observed between percent fat in the intercostal muscles and the final tenderness score; -.134, .076 and .247*. The number of chews was not significantly correlated with percent fat in the intercostal muscle.

The above data indicates that feathering is not as closely related to quality in lamb carcasses as is marbling. The correlation coefficients between marbling and feathering were .318**, .284** and .186. The objective determinations of marbling and feathering, namely, percent fat in the <u>longissimus dorsi</u> muscle and percent fat in the intercostal muscles were correlated with values of .312**, .437** and .275*. The correlation coefficients between feathering and percent fat in the <u>longissimus dorsi</u> muscle were .141, .324** and .134; and between marbling and percent fat in the intercostal muscles were .071, .384** and .288*. Although many of these correlations are

Table 4. Correlation coefficients of sensory panel scores with various other factors studied.

Variables	Correlation Coefficients 1960	1961	1962
Juiciness vs.			
U.S.D.A. Grade	.236*	.129	.319**
Color score in the *longissimus dorsi* muscle	.122	-.036	.276*
Colorimeter reading in the *longissimus dorsi* muscle	---	-.210*	.023
Feathering	.232*	.089	.088
Overflow fat score	-.251*	.098	.038
Fat streaking, flank steak	.196	.042	.260*
Fat streaking, other flank muscles	.220*	.073	.084
Estimated marbling	.286**	.130	.299**
Marbling	.379**	.103	.163
Percent fat in the *longissimus dorsi* muscle	.223*	.233*	.364**
Percent fat in the intercostal muscles	-.075	.116	.240*
Percent fat in the hotel rack	.202	.135	.248*
Percent bone in the hotel rack	-.251*	-.222*	-.164
Weight of kidney knob	.089	.033	.286*
Days of age	.256*	.025	.458**
Initial tenderness vs.			
U.S.D.A. Grade	.256*	-.002	.162
Overflow fat score	-.259*	.058	.202
Marbling	.375**	.287**	.174
Percent fat in the *longissimus dorsi* muscle	.154	.284**	.197
Percent fat in the intercostal muscles	-.214*	.173	.236*
Overflow fat, weight	.135	.216*	.031
Percent fat in the hotel rack	.000	.082	.306**
Percent lean in the hotel rack	.119	-.006	-.276*
Weight bone in the hotel rack	-.157	-.006	-.290*
Weight lean in the hotel rack	.038	.062	-.268*
Weight kidney knob	-.002	.161	.278*
Days of age	.276*	-.036	.145

Table 4. (cont'd)

Variables	Correlation Coefficients 1960	1961	1962
Number of chews vs.			
Marbling	-.415**	-.080	-.202
Percent fat in the *longissimus dorsi* muscle	-.208	-.205*	-.152
Overflow fat score	.318**	-.028	-.116
Overflow fat weight	-.209	-.218*	-.067
Kidney and pelvic fat	.125	-.043	-.253*
Weight of kidney knob	-.025	-.092	-.281*
Percent fat in the hotel rack	.034	-.044	-.275*
Percent lean in the hotel rack	-.184	-.025	.267*
Final tenderness score vs.			
Marbling	.344**	.108	.268*
Percent fat in the *longissimus dorsi* muscle	.139	.126	.272*
Percent fat in the intercostal muscles	-.134	.076	.247*
Overflow fat score	-.229*	.063	.133
Kidney and pelvic fat	.014	-.013	.238*
Percent fat in the hotel rack	-.025	.069	.337**
Percent bone in the hotel rack	-.106	-.074	-.229*
Percent lean in the hotel rack	.137	.033	-.318**
Weight of fat in the hotel rack	.027	.056	.230*
Weight of bone in the hotel rack	-.167	-.009	-.283*
Weight of lean in the hotel rack	.054	.068	-.255*
Weight of the kidney knob	.074	.096	.312**

Table 4. (concl.)

Variables	Correlation Coefficients 1960	1961	1962
Flavor intensity vs.			
Marbling	-.217*	-.019	-.180
Percent fat in the _longissimus dorsi_ muscle	-.139	-.049	-.274*
Feathering	-.295**	-.134	-.119
Percent fat in the intercostal muscles	-.387**	.007	-.052
Estimated marbling	-.248*	-.069	-.265*
Fat streaking, flank steak	-.356**	-.017	.028
Fat streaking in the other flank muscles	-.242*	-.107	.069
Color score in the _longissimus dorsi_ muscle	-.358**	.097	-.394**
Days of age	-.308**	-.078	-.325**
Flavor desirability vs.			
Marbling	.327**	.083	.045
Estimated marbling	.232*	.043	.026
Percent fat in the _longissimus dorsi_ muscle	.283**	.122	.141
Feathering	.282**	.087	-.037
Fat streaking, flank steak	.477**	-.138	.086
Fat streaking in the other flank muscles	.224*	-.090	-.030
Fat thickness over the _longissimus dorsi_ muscle	.268*	.059	.142
Cross-sectional area of the _longissimus dorsi_ muscle	.219*	.139	-.129
Color score in the _longissimus dorsi_ muscle	.325**	.038	.212
Days of age	.347**	-.057	.237*

* $(P < .05)$
** $(P < .01)$

significant they apparently are not high enough to justify substituting marbling with feathering as an indicator of quality in the carcass.

The correlation coefficients between sensory panel scores and these and various other factors studied, are shown in Table 4.

Multiple correlations of marbling with a combination of the factors, flavor desirability, initial tenderness, and juiciness, were designed to give an indication of the relationship of marbling to overall acceptability of the product. Correlation coefficients of .523** and .290** were obtained in the 1961 and 1962 data respectively. When the same combination of factors was correlated with feathering, multiple correlation coefficients of .369** and .125 were observed for the 1961 and 1962 data respectively. This also suggests that marbling may be more reliable indicator of acceptability than is feathering.

Subjective and Objective Evaluations

Determination of the relationship between subjective and objective methods of measuring quality in the carcass was one of the prime objectives of this study.

Percent fat in the longissimus dorsi muscle was used as an objective determination of marbling. The correlation coefficients observed between this and the subjective marbling score (.528**, .548** and .604**) indicate that the subjective evaluation of marbling is a consistent and reasonably accurate method of determining the amount of intramuscular fat, when it is done by trained personnel.

Percent fat in the intercostal muscle was used as an objective determination of feathering. The correlation coefficients between these two factors (-.018, .292** and .533**) were not consistent. In fact, in the first two years data an apparently stronger relationship was observed between feathering and percent fat in the _longissimus_ _dorsi_ muscle (.141, .324** and .134) than between feathering and percent fat in the intercostal muscle. The low negative correlation between feathering and percent fat in the intercostal muscle in the first years' data may be explained by the fact that determination of fat in samples containing over eight percent fat was probably less accurate due to a difference in the equipment used.

The weight of the overflow fat dissected from the hotel rack was correlated with the graders subjective evaluation of overflow fat in the carcass with values of .254*, .337**, and .380**; indicating a low but significant relationship between the objective and subjective evaluations of overflow fat.

The graders evaluation of quantity of external finish and the objective measurement of thickness of fat over the _longissimus_ _dorsi_ muscle were significantly related (.484**, .195* and .343**). Also the graders evaluation of the amount of kidney and pelvic fat was highly significantly correlated with the weight of the kidney knob, (.794**, .699** and .805**).

Objective determinations of color in the _longissimus_ _dorsi_ muscle and the rectus abdominis muscle were made only in the 1961 and 1962 data. The correlation coefficients between the graders subjective evaluation of color and colorimeter readings of the longissimus dorsi muscle were .309** and .377** for the 1961 and 1962 data respectively. The correlations between the objective and subjective determinations of color in the rectus abdominis muscle were .196* and .205 for the 1961 and 1962 data respectively.

Conformation is difficult to evaluate objectively; however, since the proportion of fat, lean, and bone in the hotel rack should give some indication of carcass composition, the correlation of conformation score with these quantity factors might give an indication of its value in predicting cutability in the carcass. The correlation coefficients between conformation score and percent fat in the hotel rack, (.262*, .227* and .429**); conformation score and weight of fat in the hotel rack (.350**, .209* and .428**); conformation score and percent lean in the hotel rack (-.056, -.119 and -.291*); as well as conformation score with the weight of lean in the hotel rack (.411**, -.080 and .103), suggests that the subjective evaluation of conformation may be a better indicator of the proportion and amount of fat in the carcass than of the proportion and amount of lean in the carcass.

Even though the percent of lean in the carcass may decrease as the conformation score increases the actual amount of lean in the carcass may increase or remain constant. Similar observations were noted in other portions of this study where percentile and actual weight values were compared. This observation is in agreement with the work of Topel (1961) in which he observed that the use of percentile values in research may often be misleading.

The correlation coefficients between the various subjective and objective evaluations of quality are summarized in Table 5.

Relationships Between the Various Quantity Factors

Cross sectional area of the longissimus dorsi muscle has been used in all species as an indicator of meatiness in the carcass. At the outset of this study there was a question as to whether the cross sectional area of the longissimus dorsi should be measured on the right or left side of the carcass, or whether it might be more desirable to measure both sides and combine the two for a total cross sectional area. In the analysis of the first years data all three measurements were included. It was observed that cross sectional area of the right and left longissimus dorsi muscles were very highly correlated (.880** and .866** respectively) with total cross sectional area. The correlation coefficient between the area of the right and left longissimus dorsi muscles was highly significant but somewhat lower (.685**), than was observed with total area. It was concluded that more accurate and consistent results would be obtained by combining the areas

Table 5. Correlation coefficients between various subjective and objective evaluations of quality.

Variables	Correlation Coefficients 1960	1961	1962
Marbling vs.			
Percent fat in the *longissimus dorsi* muscle	.528**	.548**	.604**
Feathering	.318**	.284**	.186
Percent fat in the intercostal muscles	.071	.384**	.288*
Feathering vs.			
Percent fat in the intercostal muscles	-.018	.292**	.533**
Percent fat in the *longissimus dorsi* muscle	.141	.324**	.134
Overflow fat score vs.			
Overflow fat, weight	.254*	.337**	.380**
Quantity of External Finish vs.			
Thickness of fat over the *longissimus dorsi* muscle	.484**	.195*	.343**
Kidney and Pelvic fat score vs.			
Weight of the kidney knob	.794**	.699**	.085**
Color score in the *longissimus dorsi* muscle vs.			
Colorimeter reading in the *longissimus dorsi* muscle	---	.309**	.377**
Color score in the *rectus abdominis* muscle vs.			
Colorimeter reading in the *rectus abdominis* muscle	---	.196*	.205

Table 5. (concl.)

Variables	Correlation Coefficients 1960	1961	1962
Conformation score vs.			
Percent fat in the hotel rack	.262*	.227*	.429**
Weight fat in the hotel rack	.350**	.209*	.428**
Percent lean in the hotel rack	-.056	-.119	-.291*
Weight lean in the hotel rack	.411**	-.080	.103
Quantity of external finish	.285**	.270**	.453**

* $(P < .05)$
** $(P < .01)$

of <u>longissimus dorsi</u> of both sides. All correlation coefficients with cross sectional area of the <u>longissimus dorsi</u> muscle will be with total area.

Total cross sectional area of the <u>longissimus dorsi</u> muscle was not consistently related to percent lean in the hotel rack (.082, .264** and .148), however, correlations with weight of lean in the hotel rack were consistently highly significant (.414**, .578** and .558**). The relationships with both the proportion and amount of fat and bone in the hotel rack were inconsistent but generally low and non significant.

Highly significant correlations between total cross sectional area of the <u>longissimus dorsi</u> and both slaughter weight and chilled carcass weight were observed, with values of .410**, .475** and .543**; and .450**, .499** and .534**, respectively. Dressing percent was significantly correlated with <u>longissimus dorsi</u> area the first year only, (.339**, .172 and .151).

The average thickness of fat over the longissimus dorsi muscle was highly significantly correlated with both the percent and weight of fat in the hotel rack with correlations of .664**, .631** and .511**; and .644**, .581** and .464** respectively. It was highly significantly negatively correlated with percent of both bone and lean in the hotel rack (-.568**, -.433** and -.319** for bone), (-.563**, -.469** and -.502** for lean). No significant correlations were observed with the weight of either bone or lean in the hotel rack.

Correlation coefficients of thickness of fat over the longissimus dorsi muscle with slaughter weight, chilled carcass weight, and dressing percent were .348**, .253**, .175; .511**, .402**, .289*; and .542**, .353**, .219, respectively.

The relationship of thickness of fat with other objective and subjective fat measurements was also studied. The correlations with weight of caul fat (.544**, .167 and .354**); with subjective evaluations of kidney and pelvic fat (.357**, .299** and .293**), indicate a fairly strong relationship between fat thickness and these factors. No significant relationship with overflow fat, scored objectively or subjectively, or feathering was observed. However, the percent fat in the intercostal muscles was significantly correlated with fat thickness (.196, .182* and .380**) in two years data. Correlation coefficients of .175, .142, and .312** were observed between marbling score and fat thickness. The percent fat in the longissimus dorsi muscle had a stronger relationship with fat thickness (.393**,

.198* and .302**). Apparently only a slight relationship existed between fat streakings in the flank muscles and thickness of fat over the longissimus dorsi, with correlations of .085, .298** and .252*. The relationship of thickness of fat to other factors is shown in Table 6.

In this study thickness of fat over the longissimus dorsi muscle appeared to be a better indicator of the percentage fat, lean, and bone in the carcass than was area of the longissimus dorsi muscle. However area of the longissimus dorsi muscle may be a good indicator of weight of lean in the carcass. Thickness of fat also appears to be highly correlated with internal and external fat deposits in the carcass.

The Influence of Pre-Slaughter Treatment Upon Lamb Muscle Tissue Color

In the second phase of this study, color readings taken with the Photovolt colorimeter on the longissimus dorsi muscle were highly significantly affected by treatment. A darkening of muscle tissue color was observed in the carcasses from stressed lambs, since muscle tissue from Lots IVb (exercised with a dog) and IIIb (two 10 cc. adrenalin injections) were significantly darker than the control animals. The color score as determined by the grader was also highly significantly affected by treatment in Lots IIIb and IVb, which were darker in color.

In the rectus abdominis (flank steak muscle), color, as determined with the colorimeter was very highly significantly

Table 6. Correlation coefficients between cross-sectional area of the _longissimus dorsi_ and thickness of fat over the _longissimus dorsi_ muscle with other factors studied.

Variables	Correlation Coefficients 1960	1961	1962
Cross-sectional area of the _longissimus dorsi_ muscle vs.			
Weight of lean in the hotel rack	.414**	.578**	.558**
Percent lean in the hotel rack	.082	.264**	.148
Weight of bone in the hotel rack	.160	.348**	.181
Percent bone in the hotel rack	-.224*	-.135	-.258*
Weight fat in the hotel rack	.167	.178	.179
Percent fat in the hotel rack	.073	-.094	-.037
Conformation score	.267*	.016	.132
Slaughter weight	.410**	.475**	.543**
Chilled carcass weight	.450**	.499**	.534**
Dressing percent	.339**	.172	.151
Days of age	.106	.356**	-.507**
Thickness of fat over the _longissimus dorsi_ muscle vs.			
Percent fat in the hotel rack	.664**	.631**	.511**
Percent bone in the hotel rack	-.568**	-.433**	-.319**
Percent lean in the hotel rack	-.563**	-.469**	-.502**
Weight fat in the hotel rack	.644**	.581**	.464**
Weight bone in the hotel rack	-.017	.045	-.092
Weight lean in the hotel rack	.111	.001	-.154
Slaughter weight	.348**	.253**	.175
Chilled carcass weight	.511**	.402**	.289*
Dressing percent	.542**	.353**	.219
Caul fat weight	.544**	.167	.354**
Quantity of external finish	.484**	.195*	.343**
Kidney and pelvic fat	.357**	.299**	.293**
Weight of kidney knob	.507**	.209**	.275*
Fat streaking flank steak	.085	.298**	.252*
Fat streaking in the other flank muscles	.135	.279**	.171
Marbling score	.175	.142	.312**
Percent fat in the _longissimus dorsi_ muscle	.393**	.198*	.302**
Percent fat in the intercostal muscles	.196	.182*	.380**
Days of age	.331**	-.092	.152

* ($P < .05$)
** ($P < .01$)

darker than the controls in all treatment lots except the one receiving a high level of iron in the ration. In no case was this lot significantly different from the control lot for any of the factors studied.

The graders evaluation of color in the rectus abdominis muscle was significantly affected by treatment and shows the same relationship between treatment and control as was observed in the longissimus dorsi muscle. The color score in the other flank muscles as evaluated by the grader was observed to be significantly darker in Lots IVa and b, the two exercise treatments.

An attempt was made to determine color in the intercostal muscle with the colorimeter. Ground samples of intercostal muscle were made into patties for the determination. The samples contained considerable amounts of fat which apparently affected the reading, and probably explains why no treatment effect was observed.

Mean values for colorimeter readings and color scores are listed in Table 7.

Myoglobin Concentration

Myoglobin concentration was determined in the longissimus dorsi, rectus abdominis, and intercostal muscles. Myoglobin concentration was not significantly affected by treatment in any of the muscles studied. This is in agreement with results reported by Lawrie (1953) and (1958), Briskey et al. (1959b),

Table 7. Mean lot values[1] for the various color factors studied.

Lot[2]	Colorimeter reading[3] (longissimus dorsi)**	Colorimeter reading (rectus abdominis)***	Colorimeter reading (inter-costal)	Color score (longissimus dorsi)**	Color score (rectus abdominis)*	Color score (other flank muscles)*
I	36.92[a]	47.73[a]	64.50[a]	10.38[a]	11.00[a]	11.00[a]
II	34.60[ab]	45.81[ab]	66.15[a]	10.00[a]	11.00[a]	11.00[a]
IIIa	31.34[abc]	38.22[bc]	68.75[a]	10.00[a]	11.00[a]	11.00[a]
IIIb	25.75[c]	31.18[c]	62.53[a]	8.75[b]	10.50[bc]	10.25[abc]
IVa	32.95[ab]	34.45[c]	56.90[a]	9.60[ab]	10.60[abc]	10.20[bc]
IVb	30.00[bc]	35.21[c]	60.20[a]	8.67[b]	10.33[c]	10.00[c]

[1]All values with the same superscript are not significantly different, at 5 percent level as determined by Duncans Multiple Range Test.

[2]I - control, II - iron, IIIa - adrenalin 10 cc, IIIb - adrenalin 20 cc, IVa - exercise, treadmill, IVb - exercise, sheep dog.

[3]Lower values indicate darker color.

* $(P < .05)$
** $(P < .01)$
*** $(P < .001)$

and Hedrick *et al.* (1961). This also agrees with work by Topel (1962) in which feeding of high levels of iron and copper to pigs did not affect myoglobin concentration. However, he found that myoglobin concentration was decreased by feeding rations containing very low levels of iron. Mean values for myoglobin concentration are listed in Table 8.

Hydrogen Ion Concentration

The pH of the *longissimus dorsi* muscle, as shown in Table 8, was significantly increased in the adrenalin treated lots. All lots with the exception of the lot receiving a high level of iron in the ration had a very highly significantly higher pH than the control lot in the *rectus abdominis* muscle and the intercostal muscles.

Firmness of Fat and Lean in the Carcass

Firmness of fat and lean in the carcasses was subjectively determined by the grader. Firmness of lean in the flank area was significantly affected by treatment. Lot IVa (exercised on a treadmill) and Lot IIIa (two 5 cc injections of adrenalin) were significantly less firm than in the control lot. Firmness of the *longissimus dorsi* muscle or of carcass fat was not affected by treatment.

Table 8. Mean lot values[1] for muscle myoglobin concentration and pH.

Lot[2]	Myoglobin concentration[3] (*longissimus dorsi*)	Myoglobin concentration (*rectus abdominis*)	Myoglobin concentration (inter-costal)	pH (*longissimus dorsi*)*	pH (*rectus abdominis*)***	pH inter-costal***
I	2.91[a]	1.60[a]	2.18[a]	5.54[a]	6.06[a]	5.98[a]
II	3.16[a]	1.80[a]	2.40[a]	5.53[a]	6.10[a]	6.02[a]
IIIa	3.73[a]	1.65[a]	1.93[a]	6.15[b]	6.58[b]	6.60[b]
IIIb	3.44[a]	1.84[a]	2.24[a]	6.12[b]	6.98[c]	6.76[b]
IVa	2.92[a]	1.51[a]	2.06[a]	5.53[a]	6.90[c]	6.76[b]
IVb	3.24[a]	1.66[a]	2.57[a]	5.83[ab]	6.87[bc]	6.63[b]

[1]All values with the same superscript are not significantly different at 5% level as determined by Duncans Multiple Range Test.

[2]I - control, II - iron, IIIa - adrenalin 10 cc, IIIb - adrenalin 20 cc, IVa - exercise, treadmill, IVb - exercise, sheep dog.

[3]Expressed as milligrams per gram of tissue.

* (P < .05)
*** (P < .001)

Expressible Moisture

Expressible moisture as determined by the filter paper method, and expressed as a ratio of moisture area to meat area, was not significantly affected by treatment. However, the adrenalin treated lots did show a higher water holding capacity, although it was not significant. The mean ratios for expressible moisture are listed in Table 9, along with the mean values for the firmness factors, maturity, age and U.S.D.A. Grade.

Maturity and Grade

The maturity score as designated by the grader was very highly significantly affected by treatment. It was observed that carcasses from Lot IVa (exercised on a treadmill) were scored as significantly more mature than those in other lots including the control. Actual age in days at slaughter was not significantly different between lots although it was approaching significance. U.S.D.A. grade was not significantly affected by treatment. However, it should be noted that the grader, who was unaware of treatments in the lambs, mentioned dark color in the treated lambs and rated them as more mature. Five specific instances were recorded where the grade was lowered one-third because of dark color.

Table 9. Mean lot values[1] for firmness of fat and lean, expressible moisture, maturity group, age, and U.S.D.A. Grade.

Lot[2]	Firmness of fat	Firmness of lean*	Expressible moisture[3] (longissimus dorsi)	Maturity group***	Days of age at slaughter	U.S.D.A. Grade[4]
I	9.88[a]	10.38[a]	2.63[a]	2.00[a]	128[a]	13.88[a]
II	9.50[a]	9.67[abc]	2.48[a]	2.00[a]	140[a]	12.50[a]
IIIa	8.75[a]	8.50[b]	1.93[a]	2.00[a]	114[a]	13.25[a]
IIIb	9.75[a]	9.75[abc]	2.04[a]	2.50[a]	141[a]	13.00[a]
IVa	9.40[a]	9.00[bc]	2.46[a]	3.20[b]	150[a]	12.00[a]
IVb	9.67[a]	9.67[abc]	2.57[a]	2.67[ab]	146[a]	13.67[a]

[1]All values with the same superscript are not significantly different at 5% level as determined by Duncans Multiple Range Test.

[2]I - control, II - iron, IIIa - adrenalin 10 cc, IIIb - adrenalin 20 cc, IVa - exercise, treadmill, IVb - exercise, sheep dog.

[3]Expressible moisture reported as the ratio of moisture area to muscle area with the lower value indicating a higher water holding capacity.

[4]U.S.D.A. Grade; 14 = ave. Prime, 13 = low Prime, 12 = high Choice, etc.

* ($P < .05$)
*** ($P < .001$)

Influence of Treatment on Taste Panel Scores

None of the following factors were significantly affected by any of the stress treatments; desirability of flavor, intensity of flavor, juiciness, initial tenderness, and final tenderness scores.

Influence of Age of Animal Upon Color

The quality phase of the study afforded an opportunity to study the effect of age on objective and subjective color scores in the 1961 and 1962 data. The range in age of animals in 1961 was from 94 to 147 days, a difference of 53 days from the youngest to the oldest lambs slaughtered, in 1962 the range was from 101 to 194 days, a difference of 93 days in age. The relationships observed were rather inconsistent. The correlation coefficients between days of age and the graders color score in the longissimus dorsi muscle were -.080 and .564** for the 1961 and 1962 data respectively, the latter correlation suggests an improvement in color with age. The correlation coefficients between the colorimeter reading in the longissimus dorsi muscle and age were -.194* and .061, the first correlation indicates a darkening of color with increasing age. The subjective color score in the rectus abdominis muscle was correlated with age with values of .306** and .187. These again suggest a slight improvement of color with increasing age. Correlation coefficients between the colorimeter reading in the rectus abdominis muscle and age (-.112 and .154) were not significant. The variation in age of these animals probably was not sufficiently wide to produce consistent results, when the effect of age on various factors is studied.

SUMMARY

Quality in meat involves many factors which contribute to the value of the product in terms of satisfaction to the ultimate consumer. This study was undertaken to determine the relationship between subjective and objective evaluations of quality in lamb carcasses and to determine the effect of pre-slaughter treatment upon quality with specific interest in the effect of lean tissue color on maturity score and final grade.

A total of 279 crossbred lambs were slaughtered over a 3 year period at an approximate live weight of 90 pounds. U.S.D.A. carcass grade and the various quality factors influencing grade were scored by a representative of the Federal Grading Service. The hotel rack was physically separated into fat, lean, and bone. Selected muscles were removed for further chemical and physical analysis. Taste panel evaluations were made on the loins.

In the color phase of the study, 32 crossbred lambs were randomly alloted to four treatments of eight lambs each. The treatments, consisting of feeding high levels of iron in the ration, injection with adrenalin prior to slaughter, and enforced exercise prior to slaughter were designed to produce stress in the animals. In addition to the factors determined in

the quality phase of the study, myoglobin concentration, pH, and expressible moisture were determined in selected muscles.

Feathering accounted for between 40 and 50 percent of the variation in U.S.D.A. Grade. Conformation, fat streaking in the flank steak, fat streaking in the other flank muscles, quantity of external finish, color of lean in the flank steak, overflow fat, and kidney and pelvic fat were all significantly correlated with carcass grade. Marbling and percent fat in the *longissimus dorsi* muscle were both significantly correlated with grade, with the relationship between grade and percent fat in the *longissimus dorsi* being slightly more consistent.

Considerable variation between years was noted in the strength of relationship of carcass grade to the various sensory factors. Carcass grade appears to be more closely related to juiciness than any of the other sensory factors.

Marbling was observed to be the best indicator of quality as evaluated by a taste panel. Feathering was not as good an indicator of quality even though both the objective and subjective evaluations of marbling and feathering were significantly correlated.

Most of the subjective and objective quality determinations were significantly correlated with one another, suggesting that the use of subjective methods of determining quality in the carcass may be justified. It was observed that the subjective evaluation of conformation may be a better indicator of the amount and proportion of fat in the carcass than of the amount and proportion of lean in the carcass.

Cross sectional area of the *longissimus dorsi* muscle was highly significantly correlated with weight of lean in the hotel rack. Cross sectional area of the *longissimus dorsi* appears to be influenced more by slaughter weight and chilled carcass weight than any of the other factors studied.

Thickness of fat over the *longissimus dorsi* muscle appears to be a better indicator of percent fat, lean, and bone in the carcass than was area of the *longissimus dorsi* muscle. Thickness of fat was observed to be highly correlated with internal and external fat deposits in the carcass.

Data from the color phase of the study indicates that color and pH of muscle tissue can be influenced by preslaughter treatments such as subcutaneous injections of high levels of adrenalin and exhaustive exercise. Also the maturity class may be influenced by factors other than age, such as stress conditions prior to slaughter. Although the analysis does not indicate significant differences between treatments in U.S.D.A. grade, there were specific instances in the treated lambs in which the final grade was influenced by color of the tissue.

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RELATIONSHIP OF SUBJECTIVE INDICES OF QUALITY IN LAMB CARCASSES TO OBJECTIVE MEASUREMENTS OF QUALITY AND GRADE

by

JOHN CHARLES FORREST

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Department of Animal Husbandry

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1962

This study was undertaken to determine the relationship between subjective and objective evaluations of quality in lamb carcasses and to determine the effect of pre-slaughter treatment upon quality with specific interest in the effect of lean tissue color on maturity score and final grade.

A total of 279 crossbred lambs were slaughtered over a 3 year period at an approximate live weight of 90 pounds. U.S.D.A. carcass grade and the various quality factors influencing grade were scored by a representative of the Federal Grading Service. The rack was dissected into fat, lean, bone, overflow and intercostal muscle. The longissimus dorsi and intercostal muscles were removed for fat analysis by the Modified Babcock Method. Color was determined in the longissimus dorsi and rectus abdominis with a Photovolt Reflectance Colorimeter. Loin samples were used for taste panel evaluations. In the color phase of the study myoglobin concentration, by the Poel Cyano Method, pH, and expressible moisture, by the filter paper method, were also determined in the longissimus dorsi, rectus abdominis, and intercostal muscles.

Thirty-two crossbred lambs were randomly alloted to four treatments of 8 lambs each in the color phase of the study. Lot I, was the control; Lot II, received 700 mg. iron sulfate and 70 mg. copper sulfate per pound of creep ration; Lot IIIa, 5 cc. injections of a 1:1000 solution of epinephrine hydrochloride in physiological saline were administered at 12 and again at 2 hours prior to slaughter; Lot IIIb, 10 cc. injections of the epinephrine solution were given 12 and 2 hours prior to slaughter; Lot IVa, four lambs were exercised to near exhaustion immediately prior to slaughter on a treadmill; and in Lot IVb, four lambs were exercised to near exhaustion with a sheep dog.

Feathering accounted for between 40 and 50 percent of the variation in U.S.D.A. grade. Conformation, fat streaking in the flank steak, fat streaking in the other flank muscles, quantity of external finish, color of lean in the flank steak, overflow fat, and kidney and pelvic fat were all significantly correlated with carcass grade. Marbling and percent fat in the longissimus dorsi muscle were both significantly correlated with grade.

Marbling was observed to be the best indicator of quality as evaluated by a taste panel. Feathering was not as good an indicator of quality even though both the objective and subjective evaluations of marbling and feathering were significantly correlated. Carcass grade was more closely related to juiciness than any other sensory factor.

Many subjective and objective quality evaluations were significantly correlated, suggesting that the use of subjective methods in carcass quality evaluation may be justified. Subjective conformation score was more closely related to the amount and proportion of fat in the carcass than the amount and proportion of lean.

Thickness of fat over the longissimus dorsi muscle appears to be a better indicator of the percent fat, lean, and bone in the carcass, although longissimus dorsi area was highly significantly correlated with weight of lean in the rack. Longissimus dorsi area appears to be influenced more by slaughter weight and chilled carcass weight than any of the other factors studied. Thickness of fat was observed to be highly correlated with internal and external fat deposits in the carcass.

Data from the color phase of the study indicates that color and pH of muscle tissue can be influenced by pre-slaughter treatments, such as subcutaneous injections of high levels of adrenalin and exhaustive exercise. Also the maturity class may be influenced by factors other than age, such as stress conditions prior to slaughter. Although the analysis does not indicate significant treatment differences in U.S.D.A. grade, the final grade was influenced by color of the tissue in some carcasses.