CATEGORIZING BEEF MARBLING SCORES USING VIDEO IMAGE ANALYSIS

by

ROBERT JOSEPH DANLER

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REVIEW OF LITERATURE

History of Grading

This brief history of beef grading was taken from Kiehl and Rhodes (1960), Kline et al. (1981) and USDA, (1980).

In 1916, official recognition was given to grades of beef by the U.S. Department of Agriculture for the purpose of establishing a national market news service. In 1923, tentative United States standards for graded beef were prepared and meat grading began for two government agencies, the U.S. shipping board and the Veteran Bureau Hospital.

This same year saw the publication of the first grade standards for meat in a Department Bulletin.

Meetings and hearings were held on grading with the help and support of cattle producers who formed the "Better Beef Association" in March, 1927. The Agriculture Department agreed to station graders at 10 cities. Prime and choice steer and heifer carcasses and cuts were to be graded and stamped upon request. Thus, May, 1927, was the beginning of the beef grading and stamping service.

Changes have occurred periodically in the beef grading standards. In 1939, amendments made provided for a single standard for grading and labeling of steer, heifer, and cow beef according to similar inherent quality characteristics. The amendment also changed certain grade terms for steer, heifer, and cow beef from "Medium", "Common", and "Low Cutter" to "Commercial", "Utility", and "Canner", respectively. In 1941, similar changes were made in the grade terms for bull and stag beef and the following grade terminology for all beef was established; Prime, Choice, Good, Commercial, Utility, Cutter, and Canner. In 1949, references to color of fat were dropped.

In 1950, the official standards for grades of steer, heifer, and cow beef were amended by combining the existing prime and choice grades and designating them as prime. The good grade was renamed as choice and the commercial grade was divided into two grades by designating beef produced from young animals in the top half of the grade as good while retaining the commercial grade designation for the remaining beef in that grade.

In 1956, the standards for grades of steer, heifer, and cow beef were amended by dividing the commercial grade into two grades strictly on the basis of maturity, with beef produced from young animals being designated as standard while commercial was retained as the grade name for beef produced from mature animals.

Revisions of the official standards for grades of steer heifer and cow beef were also made in 1965. They placed less emphasis on changes in maturity in the prime, choice, good, and standard grades. Also in 1965, cutability standards were adopted and a dual grading system for beef carcasses was established.

In 1973, the official standards were revised to provide separate quality grades for beef from young bulls under the class of bullock beef. In 1975, the official standards were revised to eliminate the consideration of maturity in determining the quality grade of all bullock beef and of all steer, heifer, and cow beef included in the youngest maturity group reference in those standards. Also, conformation was eliminated as a quality factor and all carcasses which were to be graded had to be both yield and quality graded.

Since the beginning of grading, it was believed that marbling and beef tenderness, and juiciness of beef were related to one another. Due to this assumed relationship, marbling is still a major contributor to final quality grade today. Since the inception of beef grading, marbling has been subjectively scored by trained grading personnel.

Current Quality Grading

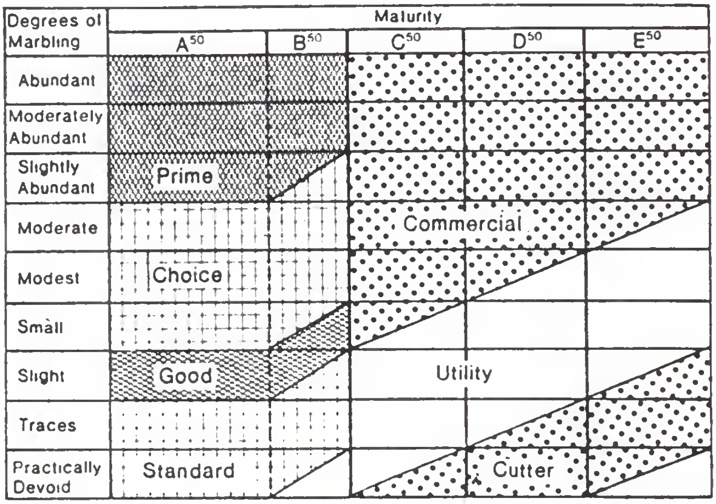
Quality grades are used in an attempt to segment beef carcasses according to indicators of palatibility of muscle tissue and are used most extensively in the grading of young steer and heifer carcasses. Since most steers and heifers slaughtered are from twelve to twenty months of age, the vast majority of them grade US Prime, Choice, Good, and Standard. The factors which determine the carcass quality grades are determined by USDA graders who subjectively appraise carcass skeletal maturity, amount of marbling, and lean color, texture and firmness (USDA, 1980). All these except skeletal maturity are determined by evaluating the exposed cut surface of the longissimus muscle between the 12th and 13th ribs.

Nine degrees of marbling, from least to most, are practically devoid, traces, slight, small, modest, moderate, slightly abundant, moderately abundant, and abundant. These marbling degrees and their relationship to carcass grade are shown in Figure 1 (Boggs and Merkel, 1981).

Marbling accounts for at least 80% of the variation in carcass grades according to Zinn et al. (1961), Alsmeyer et al. (1959) and Campion et al. (1975). Color of lean influences grade as it is an indicator of maturity. In extreme stress, a resulting color problem called dark cutting beef (Hall et al., 1944), influences final quality grade. Finer texture and firmer lean are identified as superior quality traits (Boggs and Merkel, 1981). It is generally agreed that as animal age advances, tenderness is decreased. Berry et al. (1974) found muscle samples from youthful carcasses to be superior in palatibility to those of more mature carcasses, but his findings were not consistent with current USDA maturity groupings. Breidenstein et al. (1968), found E maturity markedly less tender than A or B maturities, but little difference existed between A and B maturity. Tuma et al. (1962) also found that tenderness of longissimus dorsi steaks, as evaluated by Warner Bratzler Shear and the taste panel, decreased ($P<.005$) with advancing animal age.

Figure 1

Relationship of Marbling and Maturity
As Used in Determining
Final Beef Carcass Quality Grade



Marbling and Beef Tenderness

Marbling has been considered important in predicting tenderness since the original USDA grade standards were officially established in 1927. Since that time, many researchers have attempted to determine the degree of relationship or nonrelationship between marbling and tenderness. Kropf and Graf (1959) found higher ether extract values, lower shear values, and higher tenderness ratings were associated with higher grades. McBee and Wiles (1967) found tenderness, juiciness and flavor increased linearly with additional marbling. Breidenstein et al. (1968) and Garcia de Siles et al. (1977), who found generally more improved palatability characteristics with increased marbling, agree with these results.

Not all researchers have agreed tenderness is strongly influenced by marbling. Alsmeyer et al. (1959) found marbling accounted for 80% of the variation in federal beef grades, but only 5-6% of the variation in panel tenderness ratings. Tuma et al. (1962) reported "slightly abundant" marbling, as compared to a "slight amount" of marbling did not enhance the tenderness of steaks from 18 month old animals. Huffman et al. (1974) agreed, as he found no significant difference in taste panel and Warner Bratzler shear results in prime, choice, and good carcasses. Campion et al. (1975) found components of quality grades accounted for no more than 10% of the variation in any of the taste panel measurements.

Grading Accuracy

In the Report to the Congress by the Comptroller General (1978), the Department of Agriculture needed to improve its accuracy and uniformity of beef grading. It was found that 21% of the 2,215 carcasses examined had been misgraded. Furthermore, uniformity of application was different among all six of the main stations surveyed.

One cause for inaccurate grading was excessive speed at which carcasses passed the grader. In many cases, yield and quality grades must be determined subjectively in 10 to 15 seconds. Rate of error was shown to increase as the chain speed or number of carcasses graded per hour increased. Packers do not favor reduced rail speeds. Slower rail speeds would translate into losses in carcass revenue. A five percent reduction in rail speed would result in a loss of carcass revenues of $4.5 million per year as stated by a midwest packer, Comptroller General, (1978).

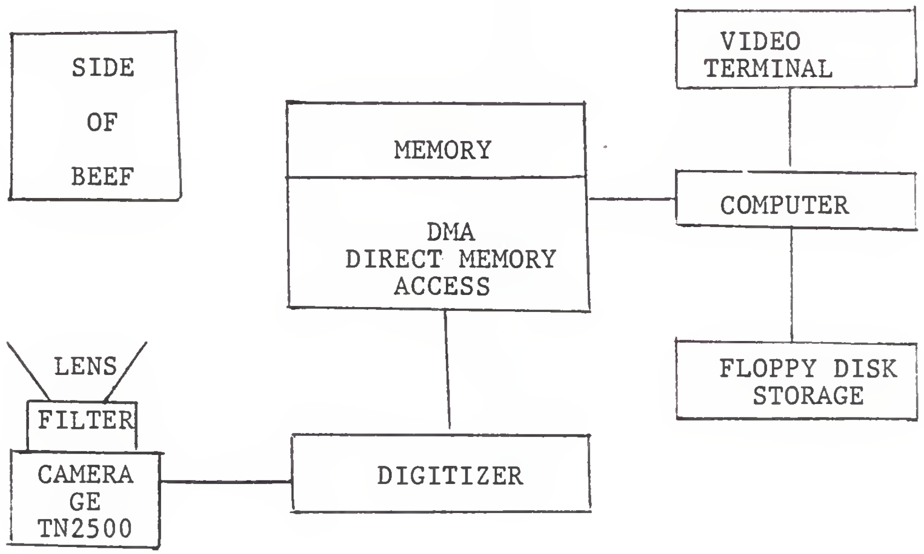
It was recommended to the secretary of agriculture, that USDA increase efforts to develop instruments to accurately measure those beef carcass characteristics used to determine grades. Work is currently being done with Ultrasonic and with Video Image Analysis (VIA). Instrument grading will improve both accuracy and consistency of grade application within and between main stations.

Video Image Analysis

Video Image Analysis was studied in a project started at Kansas State University in 1977 in a cooperative effort between the Department of Electrical and Computer Engineering and the Department of Animal Science and Industry. It has been used to determine objective parameters of the yield grading equation. The system as explained by Lin (1978) and Lenhert et al. (1985) consists of the block skematic shown in Figure 2.

Figure 2

Block Schematic of VIA



The VIA takes an image of the cross-sectional area of a beef carcass longissimus-muscle and by reading light intensity, digitizes, and classifies which parts of the picture are background, fat, or meat. This digitized picture is then interpreted by an Intel single board computer iSBC 86/12A. Data calculated from this digitized picture includes total surface area, total fat and total meat area in measurement units, and as a percentage of the total; fat thickness as measured by USDA, number of pieces of marbling and a color reflectance score. This information can all be either displayed on a Video terminal and/or printed, (Figure 2) or stored in a floppy disk.

Cross et al. (1983) developed equations using the following instrument measured traits: total lean area, percentage total fat area and fat thickness, along with rib weight. He used the equation to predict kilograms of lean from 9-10-11th rib section vs. the best equation using traits determined by the grader which were hot carcass wt., actual fat thickness, and rib eye area. VIA had a coefficient of determination of (93.6%) vs. (84.3%) for the best equation using grader measured traits.

Wassenberg (1983) selected 115 steers representative of the total beef population. A committee of three trained experts on grading beef carcasses evaluated each carcass for all USDA yield and quality grade factors. Committee scores were averaged and the average score was assigned to each carcass. The VIA was then used three times on each carcass and an average of the three readings was used as the VIA value. Carcasses were weighed and cut into wholesale cuts and the cuts were trimmed and weighed to get actual yield. The equation developed from the VIA to predict total primal cut out yield (percentage) had an R^2 x 100 of 46.36 which included side weight and VIA measured traits of fat area percentage, lean area percentage and color score. USDA yield grade traits had an R^2 x 100 of 46.35%. The VIA equation had a predictive accuracy of 95.63% compared with a 94.29% predictive value for the USDA yield grade traits scored by the committee on total primal cut out lean yield. The VIA predicted the 12th rib longissimus-muscle area, preliminary yield grade and adjusted preliminary yield grade with accuracies of 81.81, 84.71, and 77.64, respectively.

The conclusion of both studies was that VIA showed considerable promise in minimizing grading error by the grader.

VIA work is also being done by Newman at the Meat Research Institute in Great Britain. Newman (1983) reported correlations of 0.94 to 0.99 when comparing fat percentages of VIA with total composition by dissection for bacon, beef, ham and pork.

The results of the yield grade portion of grading using the VIA Measured traits is very encouraging, but little to no progress has been reported on using VIA for analyzing marbling and quality traits.

Attempts to Quantify Marbling

It is widely accepted that even trained graders are inconsistent in evaluating marbling degrees and one grader differs from another. Others who evaluate marbling degrees, such as researchers, may be even more inconsistent than graders.

Several attempts have been made to develop a means of objectively measuring marbling. Blumer and Fleming (1959) placed samples under the magnifying glass of a colony counter normally used for plate counting colonies of bacteria, and counted the number of fat deposits and measured each deposit having a surface area of 2 square millimeter or larger. They found a correlation of .81 beween ether extract and fat area and .82 between ether extract and number of fat deposits on the lean surface.

Orme et al. (1958) reported that specific gravity was a successful measure of marbling and was highly related to steak chemical fat. In a later study, Cole et al. (1960) found a negative correlation coefficient of .77 ($p < .01$) between marbling score and specific gravity. They also stated that specific gravity only accounted for 10-20% of the variation in beef eating quality characteristics.

Cook and Bray (1961) developed a macrophotographic technique to measure marbling amount and marbling distribution. They used a positive transparency of a photograph taken of a rib steak and measured the light transmittance through the transparency. They obtained a correlation coefficient of .88 ($p < .01$) between percent light transmittance and marbling score and .83 ($p < .01$) between chemical fat and light transmittance. However, in this study, they examined steaks with large differences in marbling degree.

Hale (1981) used an adaptation of Blumer and Fleming (1959) to determine total fat surface area. A transparency of graph paper with squares 1.27 mm2 in area was laid over each steak and the border of the longissimus-muscle was traced. A measurement of the amount of visible fat within the loin eye surface was established by placing a dot in and counting each 1.27 mm2 square which was at least half full with fat. Total fat on loin eye surface was then calculated. Simple correlation coefficients between marbling score and measurement of marbling amount and texture were 0.94 ($p < .0001$ percent surface fat/loin eye area), 0.84 (number of fat deposits) and 0.68 (average fat deposit size), and between chemical fat and marbling score ($r = 0.83$). Objectively measured marbling has a strong relationship to marbling score (0.94, $p < .0001$) according to Hale (1981). Moody and Cassens (1968) made tracings of visual marbling on acetate paper and then measured total area. They reported a 0.57 ($p < .05$) correlation coefficient between chemical fat and total fat area as a percent of longissimus-muscle. Reddy (1969) similarly stated that the percent of histological fat on the loin eye surface increased with an increase from small to moderate marbling scores.

Many researchers have found marbling score highly correlated with ether extract (Blumer and Fleming, 1959, r = .81; Walters et al., 1965, r = .91; Dikeman et al., 1972, r = .79; Campion et al., 1975, r = .78; and Hale, 1981, r = .83).

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SUMMARY

Sixty-six rib steaks were used to test Video Image Analysis (VIA) ability to measure longissimus-muscle area and categorize steaks according to marbling scores.

All steaks were first measured for total surface area, which included lean and fat of intact steaks. Then, the outside fat was removed. A three member trained panel individually determined marbling scores to the nearest 10% of a marbling degree and color score on a five point scale. Panel members' scores were averaged to determine individual steak scores.

Data taken using the VIA included total surface area, total fat area and percentage, total lean area and percentage, number of pieces of fat, and a color reflectance score. Number of fat pieces per unit area was then calculated.

Simple correlation coefficients calculated were marbling score with chemical fat (0.76), marbling score and calories per 100 grams (0.83), marbling score and VIA measured color (0.41), marbling score and VIA total lean percentage (0.21), marbling score and VIA total fat percentage (0.21), and marbling score and VIA number of fat pieces per unit area (0.49). Simple correlations were also determined between VIA total area of steaks with outside fat on and planimeter reading; and VIA total area of longissimus-muscle (fat off) with planimeter reading. Both correlations above were 0.98 indicating the VIA had extremely good accuracy in measuring total cut surface

area. Color score measured by VIA versus panel color score had a correlation coefficient of (-0.75).

Total VIA fat percentage was correlated (r=0.37) with ether extract. When steaks were segmented by marbling degrees and average VIA total fat percentages by marbling degrees were calculated, steaks with slight marbling scores had the lowest average fat percentage (2.3); while those with moderately abundant marbling scores had the highest average fat percentage (3.8).

The best regression equation using VIA measured traits for predicting marbling scores had a coefficient of determination (R^2 x 100) = 0.61. This equation was: 1254.70 - 20.97(VIA total area) - 19.23(VIA color) + 98.59(VIA number of fat pieces/unit area).

INTRODUCTION

Marbling score has been and continues to be a subjectively measured quality grade factor. With as high as 11% yield and 10% quality grading errors having been reported (Comptroller General, 1978), the need for an objective measuring device for both quality and yield grading has been shown. In an attempt to measure some of the quality and yield grade factors, the Video Image Analyses instrument was designed and developed at Kansas State University. This instrument has been tested by Cross et al. (1983) and by Wassenberg (1983) for its ability to quantify, measure and predict yields of primal rib cuts and edible portion of the four major beef primals. Neither of these workers investigated the ability of the VIA to quantify marbling and thus to function as an instrument to categorize carcasses according to this quality trait.

With this in mind, this study was designed with the following objectives;

1) To compare the VIA's ability to measure the surface area of steaks compared to planimeter measured surface area.

2) To look at interrelationships between VIA measurements, panel marbling and chemical analysis.

3) To determine percentage of fat/unit as measured by the VIA in steaks of different marbling scores.

4) To determine the VIA's ability to categorize steaks according to level of marbling.

EXPERIMENTAL PROCEDURE

Product Origin

Sixty-six rib steaks with differing degrees of marbling were collected, vacuum packaged, frozen, and stored at -25°C for later analysis.

Each steak was then thawed and a Berkel Model 818 meat slicer was used to remove a .64cm slice from the steak surface to expose a fresh surface. Steaks were allowed to bloom for 30 minutes, an acetate tracing was made of the total surface area of the steak (lean plus fat) and a VIA reading was taken. Measurements taken with the VIA are shown in table 1. Steaks were trimmed of external fat and other muscles leaving only the longissimus-muscle. Three panel members independently scored marbling to the nearest 10% of a marbling degree, (table 2). Each member also scored color on a scale of 1 to 5, (table 2). An acetate tracing and three additional VIA readings were taken of the total surface area of the trimmed longissimus-muscle. The three VIA readings of the untrimmed and trimmed steaks were averaged for the final VIA measurements and marbling and color scores of the three member panel were also averaged. Planimeter measurements of the total surface area of untrimmed and trimmed steaks were determined.

Chemical Analysis

Many researchers have reported location variation in

TABLE 1. VIDEO IMAGE ANALYZER READINGS

1)	Total area
2)	Total fat area
3)	Total meat area
4)	Total fat percentage
5)	Total meat percentage
6)	Number of fat pieces
7)	Color reflectance score[a]

[a] VIA color reflectance range
0 = Black
Lower score darker red
Higher score lighter red
128 = Bright white

TABLE 2. PANEL SCORE

Color	Marbling	
1) Very light cherry red	100-199	Traces
2) Cherry red	200-299	Slight
3) Slightly dark red	300-399	Small
4) Moderately dark red	400-499	Modest
5) Dark red	500-599	Moderate
	600-699	Sl. Abundant[a]
	700-799	M. Abundant[b]

[a] Sl. = Slightly Abundant

[b] M. = Moderately Abundant

marbling content within longissimus-muscle (Blumer and Fleming 1959; Cook et al., 1964; Reddy, 1968). In order to limit this source of variation, a .25 cm slice was removed from each steak from the surface which was measured by the VIA and scored by the panel.

Each slice was frozen in liquid nitrogen, pulverized in a Waring Blender and stored at -25°C until analyzed for ether extract.

The remainder of the steak sample was ground twice through a 3/16 inch plate, frozen at -25°C until caloric content could be analyzed using Bomb Calorimeter. Ether extract and caloric content were done according to AOAC (1984).

Statistical Analysis

Simple correlation coefficients were calculated (SAS 1982) to determine the relationship between panel scored traits, VIA measurements, planimeter measurements and chemical analysis results. Means and standard deviations were calculated for results of chemical analysis and VIA measurements for marbling degree categories. Stepwise regression procedures were used to establish a prediction equation for marbling using VIA measurements.

RESULTS AND DISCUSSION

Means and Standard Deviations

Means and standard deviations for VIA and planimeter measurements of total steak surface area are shown on table 3. When we look at these means and standard deviations, we find that VIA measured total surface area of the untrimmed and trimmed steaks was essentially the same as those measured using the planimeter. This would indicate that total surface area of meat cuts can quickly and accurately be measured using VIA.

Table 4 shows means and standard deviations for steak color and marbling as scored by the three member panel. The mean score for steaks with slight (USDA Good) marbling was in the upper 1/2 of that degree while those for small (USDA Choice minus) were in the lower half of that marbling degree. Mean values for small up through slightly abundant were all essentially one complete marbling degree apart. The mean difference between slightly abundant (low prime marbling) and moderately abundant was similar to the mean difference between slight and small. Variance within each degree of marbling was very similar with the exception of moderately abundant where only two steaks were scored.

Table 5 shows means and standard deviations of the traits measured on the trimmed steaks. Fat pieces per unit of surface area is a measure that was calculated by dividing the total number of fat pieces counted by the VIA by the total surface

TABLE 3. MEANS AND STANDARD DEVIATION OF VIDEO IMAGE ANALYZER AND PLANIMETER MEASUREMENTS OF STEAK TOTAL SURFACE AREA

Measurements	N	Untrimmed steaks		Trimmed steaks	
		mean cm^2	st dev[a]	mean cm^2	st dev[a]
VIA total area	66	127.58	23.35	68.30	13.16
Planimeter total area	66	126.10	23.35	70.18	14.19

[a] Standard deviation

TABLE 4. MEANS AND STANDARD DEVIATIONS FOR PANEL MARBLING SCORE BY PERCENTAGE

Variable	N	$\bar{x}$[a]	Standard deviation
Slight	12	261	21
Small	23	341	27
Modest	6	440	36
Moderate	14	547	31
Slightly Abundant	9	645	30
Moderately Abundant	2	716	14

[a] See marbling scoring method, table 2.

TABLE 5. MEANS AND STANDARD DEVIATIONS
OF VIDEO IMAGE ANALYZER MEASUREMENTS OF TRIMMED STEAKS

Variables	N	Mean	Standard deviation
Total surface area	66	68.30 cm^2	13.16 cm^2
Total fat area	66	2.00 cm^2	1.23 cm^2
Total meat area	66	66.30 cm^2	12.51 cm^2
Total fat percentage	66	2.83	1.47
Total meat percentage	66	97.07	1.47
Color reflectance score	66	41.21	4.15
Fat pieces/unit area	66	1.95	.89

area of the trimmed steak. The other measures in table 5 were directly measured by the VIA.

Correlations Between VIA Measurements, Ether Extracts, Caloric Content, Marbling, and Planimeter Readings

Correlations between VIA total area and planimeter measurement of the untrimmed and trimmed steaks were both 0.98. Obviously, VIA is very accurate in measuring total surface area. In table 3, means and standard deviations of VIA measured and planimeter measured areas were almost identical for both untrimmed and trimmed steaks.

When we look at VIA color reflectance readings versus panel color scores, a correlation of -0.76 was found. The negative relationship results due to desirable panel scores being low numbers and the reverse being true with VIA measured color. A correlation of -0.76 indicates that the VIA is capable of recognizing color differences. Since VIA measures color over a wide scale (table 2), it is entirely plausible that it does a much superior and more consistent job of categorizing color differences than the panel who scored on only a 5 point scale. In other words, the consistency of the panel at scoring color may be more questionable than the VIA. The camera used was 1979 technology. With current technology upgrading the camera could improve VIA color relationship to panel color scores.

Correlations between VIA measured fat area and marbling score for trimmed steaks was only 0.06 (table 6). This points out that marbling when measured by the VIA must be measured on a per unit area basis or percentage to duplicate what is done by the human when scoring marbling. When VIA measured fat is expressed as a percentage of surface area, the correlation between it and marbling is improved to 0.21. This low correlation may tell us that at present the VIA is not precise enough to give us an accurate percentage reading. The highest correlation between VIA trimmed steak measurements and marbling score resulted when correlating VIA measured fat pieces/unit area with panel marbling score (0.49). Fat pieces/unit area is calculated by dividing VIA number of fat pieces by VIA total area. VIA color was related to marbling score at 0.41. Both these correlations had $p < .01$ and showed definite promise of being used to predict or measure marbling degrees using the VIA.

Some of the lower correlations between VIA readings and marbling scores may be because it is not sensitive enough to pick up and measure all marbling in the cut surface. Newman, (1984), reported that if either meat or fat smears occurred, that VIA readings were less accurate.

VIA total fat percentage correlation to marbling score ($r = .21$) is low compared to other methods of objectively measured total surface fat percentage versus marbling score, (Moody and Cassens, 1968, and Hale, 1981, who found $r = 0.57$ and $r = 0.94$, respectively). With this in mind, we must conclude that at

TABLE 6. CORRELATION COEFFICIENT COMPARING MARLING SCORE, VIDEO IMAGE ANALYZER MEASUREMENT, AND CHEMICAL ANALYSIS OF TRIMMED STEAKS

		1	2	3	4	5	6	7	8	9
1) Marbling score		----								
		----								
2) VIA total fat area	r	.06	----							
	P	.640	----							
3) VIA total lean area	r	.29	.47	----						
	P	.020	.001	----						
4) VIA total fat %	r	.21	.92	.11	----					
	P	.090	.001	.359	----					
5) VIA total lean %	r	.21	-.92	-.11	-1.00	----				
	P	.090	.001	.359	.001	----				
6) VIA color	r	.41	.17	-.05	.16	-.15	----			
	P	.001	.177	.689	.203	.203	----			
7) Fat pieces per unit area	r	.49	.51	-.03	-.59	-.37	.22	----		
	P	.001	.001	.807	.001	.002	.080	----		
8) Chemical LD[a] fat %	r	.76	.22	-.19	.37	-.35	-.26	.40	----	
	P	.001	.079	.120	.002	.004	.033	.001	----	
9) LD caloric content	r	.83	.12	-.25	.26	-.26	-.28	.45	.75	--
	P	.001	.322	.042	.036	.036	.021	.002	.001	--

[a] LD - Longissmuss dorsi

present the VIA doesn't correlate very strongly with marbling.

Ether extract and panel marbling score were correlated at 0.76. This relationship is similar to that found by many researchers. (Blumer and Fleming, 1959, 0.81, Dikeman et al., 1972, 0.79, Campion et al., 1975, 0.78, Hale, 1981, 0.83). The highest correlations for VIA measurements versus ether extract were for VIA total fat percent (r = 0.37) and fat pieces per unit area (r = 0.40). These VIA readings are attempts to measure fat, ether extracts are related to fat content, so we would expect them to be higher correlated than other VIA readings.

Caloric content as determined by use of the bomb calorimeter had a high correlation to ether extract at 0.76 and marbling score at 0.83. We'd expect these to be high as fat has a higher caloric content than muscle. VIA fat pieces per unit area was also moderately correlated to caloric content at 0.45.

Comparison of VIA Total Fat Percentage, Ether Extract, Caloric Content and Fat Pieces Per Unit Area By Marbling Groups

The means and standard deviations for VIA total fat percentage, fat pieces/unit area, ether extract, and longissimuss-muscle caloric content categorized by panel marbling score are given in table 7. The means for ether extract percentage by marbling degree (table 7) increase as panel marbling scores go up. This indicates that panel members

TABLE 7. MEANS AND STANDARD DEVIATIONS FOR ETHER EXTRACT, VIDEO IMAGE ANALYZER PERCENT SURFACE FAT, CALORIC CONTENT AND FAT PIECES PER UNIT AREA BY PANEL SCORED MARBLING GROUPS OF TRIMMED STEAKS

Marbling degree	Number	% Ether extract	SD	VIA % surface fat	SD	Cal. 100 g.	SD	FPUA	SD
Slight	12	3.9^{c}	1.3	2.3^{c}	1.6	165^{c}	7.3	1.2^{c}	.36
Small	23	4.0^{cd}	1.6	2.8^{c}	1.5	176^{d}	9.7	1.9^{cd}	.78
Modest	6	5.3^{cd}	2.3	2.9^{c}	1.8	181^{d}	10.5	1.6^{cd}	.36
Moderate	14	6.4^{d}	2.1	2.9^{c}	1.3	196^{e}	16.2	2.5^{d}	.97
Slightly Abundant	9	9.0^{e}	1.0	3.3^{c}	1.5	208^{f}	11.9	2.4^{d}	.95
Moderately Abundant	2	9.4^{e}	.12	3.9^{c}	.73	218^{f}	.7	2.8^{d}	.93

[a] Cal. 100 g. = Calories per 100 g.
[b] FPUA = Fat Pieces Per Unit Area
[c,d,e,f] Means Without a Common Superscript Differ ($p<.05$)

were ranking marbling scores correctly in relationship to ether extract percentage. These values are similar to those reported by Campion et al. (1975) and Hale (1981) except they were lower than those reported by Campion in the slight through moderate degree but higher in slightly abundant. When looking at differences of the mean at the ($p < .05$) level, we find that abundant and slightly abundant were different from the three choice grade marbling levels, and that moderate (USDA Choice plus) was different from slight (USDA Good grade).

VIA measured total fat percentage was much lower than measured surface fat percentage by marbling groups as reported by Hale 1981, (4.9% slight, 6.6% small, 8.2% modest, 12.7% moderate, and 16.2% slightly abundant). Reddy (1968) and Hale (1981) also reported that measured surface fat percentage was higher than ether extract percentage especially in higher marbling degrees. In this study, VIA total fat percentage of trimmed steaks was lower than ether extract reading in all marbling degrees, (table 7). VIA total fat percentage of trimmed steaks ranged from a low of 2.3% in slight to a high of 3.9% in moderately abundant. These results indicate that this current VIA model may lack the sensitivity needed to differentiate between similar marbling degrees.

Steaks with slight marbling scores which would grade USDA good, have an average of 0.5% less VIA total fat percentage than those with small marbling, (table 7). For the three marbling degrees found in USDA Choice grade, VIA measured total fat percentage is only 0.1% greater in moderate (Choice plus marbling) versus small (Choice minus marbling). Mean VIA measured total fat percentage in low Prime (slightly abundant marbling) steaks has 0.4% more VIA measured total fat percentage than high choice marbling. These results seem to suggest the feasibility of the VIA being more successful at categorizing steaks according to USDA grade rather than to individual marbling degree.

Caloric content definitely increased by degree of marbling, (table 7). Steaks with slight marbling had the fewest calories at 165 per 100 g. while those steaks with average Prime marbling (moderately abundant) had the most calories at 218 per 100 g. Statistical differences ($p<.05$) existed between mean scores for slight and small and between modest and moderate along with differences between moderate and slightly abundant. This caloric content relates directly with ether extract percentage found in the varying degrees of marbling.

VIA Prediction Equations for Marbling

Since one of the objectives of this study was to determine the ability of the VIA to predict marbling degree, stepwise regression analysis was used to determine which VIA measures were most useful to determine marbling degree. The best fit regression model included the following VIA measurements: VIA total area, color reflectance and fat pieces/unit area. The equation derived using these independent variables was: 1254.7 - 20.97 (VIA total are) - 19.23 (VIA color) + 98.59 (fat pieces/unit area) = number of fat pieces/total surface area. This equation had a coefficient of determination of 0.61. Thus in these steaks, the VIA using this regression model was capable of accounting for 61% of the variation present in marbling score.

Discussion

This study suggests that the VIA is extremely accurate at measuring total surface areas of either untrimmed or trimmed steaks. This accuracy precision and the speed with which it can be done suggests some potential uses of the VIA in quality control programs where consistency of surface areas is important.

The means by marbling degree (table 7) suggests the VIA has potential capabilities of categorizing steaks by marbling degree. No statistical differences were noted in the means for VIA percentage surface fat by marbling degree. This date suggests that the VIA instrument used in this study does not differentiate fat from lean sufficiently to use it as a quality grading instrument where marbling is the chief determining factor. The ability to differentiate fat from lean might be greatly improved in the VIA by updating the camera technology used in the VIA. The camera used in the VIA in this study is a GE TN2500 which is the original camera used in VIA's development in 1979.

Caloric content per 100 grams of tissue increases by 32% when marbling score goes from slight to moderately abundant. This would indicate the potential need for labeling of caloric content by marbling degree.

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CATOGERIZING BEEF MARBLING

SCORES USING VIDEO IMAGE ANALYSIS

by

ROBERT J. DANLER

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AN ABSTRACT OF A MASTER'S THESIS

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Sixty-six rib steaks were used to test Video Image Analysis (VIA) ability to measure longissimus-muscle area and categorize steaks according to marbling scores.

All steaks were first measured for total surface area, which included lean and fat of intact steaks. Then, the outside fat was removed. A three member trained panel individually determined marbling scores to the nearest 10% of a marbling degree and color score on a five point scale. Panel members' scores were averaged to determine individual steak scores.

Data taken using the VIA included total surface area, total fat area and percentage, total lean area and percentage, number of pieces of fat, and a color reflectance score. Number of fat pieces per unit area was then calculated.

Simple correlation coefficients calculated were marbling score with chemical fat (0.76), marbling score and calories per 100 grams (0.83), marbling score and VIA measured color (0.41), marbling score and VIA total lean percentage (0.21), marbling score and VIA total fat percentage (0.21), and marbling score and VIA number of fat pieces per unit area (0.49). Simple correlations were also determined between VIA total area of steaks with outside fat on and planimeter reading; and VIA total area of longissimus-muscle (fat off) with planimeter reading. Both correlations above were 0.98 indicating the VIA had extremely good accuracy in measuring total cut surface area. Color score measured by VIA versus panel color score had a correlation coefficient of (-0.75).

Total VIA fat percentage was correlated (r=0.37) with ether extract. When steaks were segmented by marbling degrees and average VIA total fat percentages by marbling degrees were calculated, steaks with slight marbling scores had the lowest average fat percentage (2.3); while those with moderately abundant marbling scores had the highest average fat percentage (3.8).

The best regression equation using VIA measured traits for predicting marbling scores had a coefficient of determination (R^2 x 100) = 0.61. This equation was: 1254.70 - 20.97(VIA total area) - 19.23(VIA color) + 98.59(VIA number of fat pieces/unit area).