The Evaluation of Qualities of Beef with Standard Simulation Models: A Method for Evaluating the Degree of Marbling in Beef

H.NAKAI, T.IKEDA, S.ANDO and R.TANABE

National Institute of Animal Industry, Tukuba Norindanchi Ibaraki 305, Japan

SUMMARY: Trials were made to establish an easy and objective method of judging meat color, fat color and marbling, which are the most important criteria for evaluating meat quality in cattle. The method, which makes use of standard simulation models of beef color, beef fat color and beef marbling, can replace the old way of relying on an experienced eye alone. Since, recently, the extent of marbling in loin eye (muscle-section of longissimus dorsi) can be appraised accurately with an image analyzer, the authors numerically expressed the extent of marbling in loin eye by comparing with the photographs of 6 grades (+0 to +5) published by the Japan Meat Grading Association, and set the standard values for each grade of marbling. Then, standard models of beef marbling were produced to establish an easy and objective method of judging the extent of beef marbling. The authors prepared a set of 12 grades of marbling models, in which each grade corresponds to 0, 0^+, 1^-, 1, 1^+, 2^-, 2, 2^+, 3^-, 3, 4 or 5 of the Japanese marbling grade system. The standard models of beef marbling can be applied to every part of the surface of a loin eye section of beef carcass or loin cut. Judging marbling of beef carcass, the models were brought near the surface of the loin eye section which was chilled beforehand.

INTRODUCTION:

Before 1988, the Japanese market values for sections of beef was figured by a combination of evaluation based on overall weight and an evaluation based on meat quality. However, since there was no standardized system for carrying out this evaluation procedure objectively such evaluation depended largely on the experience of each evaluator, and was thus rather subjective. However with the modernization of the meat market in recent years, there has been a growing need for the formulation of an objective evaluation standard that will be recognized as fair and objective by producers, wholesalers, meat handlers and consumers. It was with this in mind that new guidelines have been developed.

The procedure we are advocating was developed with this as a background. Since the evaluation of beef and beef fat color with standard simulation models has already been published at a symposium entitled "Electronic Evaluation of Meat in Support of Value-Based Marketing" held at Purdue University on March 1991, we describe "A Method for Evaluating the Degree of Marbling in Beef" in this paper.

The usual method for judging the degree of marbling in beef longissimus thoracis loin eye and the surrounding meat has been to merely judge by eye. There has been an attempt in Japan to make this more objective through the use of comparative pictures introduced by the Japan Meat Grading Association with values of +0 to +5. However, the fine details of marbling were difficult to see in the pictures, and their use required a lot of experience on the part of the judge. It was for this reason that the research presented here was conducted.

First of all, using the pictures of marbling in the various grade levels, we developed a method of numerical evaluation of the amount of marbling, and then we attempted to establish standard values that could serve as evaluation standards. Following that, we made simulation models of beef marbling based on these standard values believing that they could be used to grade beef marbling more accurately and easily than by previous methods.

MEASURING METHODS USED IN DETERMINING STANDARD VALUES IN BEEF MARBLING:

1. Methodology

1) Use of a spectrophotometer

The picture negatives used in making pictures of the standard samples of beef loin eye were blown up to a standardized size (about 9.7 by 12.5 cm), and were then analyzed spectrographically. Light absorption patterns for areas of red meat and fat were compared, and the wavelength at which the greatest difference occurred was found to be 563.3 nm. Next, using that wavelength, a Beckmann DU-8 spectrophotometer incorporating a Gel scanning device was used to measure the light absorption values along the scanning lines in the picture. As is shown in Fig. 1, the picture of the loin eye was analyzed using the scanner along 3 lines running along the length of the eye and 3 lines running across the eye. The results are shown in Fig. 2. Since the light absorption value peaked at areas that corresponded to marbled fat within the loin eye, the first step in analysis of the data was to determine the area of the spike by using the peak value and the width of the spike at half of the peak value. From this data, the total sum and the average values were determined. The conditions under which the Gel scanning was performed were: chart speed, 10 cm/min., scanning speed, 2 cm/min and the scanning slit at 0.1 mm.

2) Using an Image Analyzer

By using an image analyzer, it is possible to determine the dimensions of the major and minor axes and the perimeter of each of the marbled fat seams in the loin eye and the total area of fat within the cross-section. In order to accomplish this, we used a Joyce-Loebl Magiscan Model 2 image analyzer, and analyzed pictures of a beef roast cross-section blown up to a standard size to determine the total area of marbled fat along with the dimensions of each marbled fat seam.

2. Results and Discussion

1) On the use of a spectrophotometer

Table 1 shows the results obtained from analysis of the six standard pictures of loin eye cross-sections used by the Japan Meat Grading Association. The analysis was done along 3 lines running parallel to each of the major and minor axes of the loin eye (as is shown in Fig. 1). The total area of fat, which corresponds to the degree of marbling, increases as grades go from +0 to +5, and this trend is more pronounced along the lines parallel to the major axis. However, while the average value, which is obtained by dividing the total area by the number of peaks, corresponds quite well with the standard value for marbling when looked at along the major axis, the same is not true for values along the minor axis. This is apparently related to the fact that the lines of marbling in loin eye roast generally run parallel to the minor axis. This results in the values of scanning parallel to the minor axis being greatly affected by whether the scanning line happens to run along a marbling seam or not. Moving the scanning line slightly one way or the other can result in large differences in the areas of the peaks.

It is for this reason that we decided that meaningful values for the degree of marbling could be assigned from a graph of the light absorption obtained from scanning pictures of roast cross-sections with a spectrophotometer only along the major axis of the loin eye. Likewise, we came to the conclusion that accurate evaluation of the degree of marbling required at least 3 lines of scanning along the major axis, taking the average value of the scans.

2) Using an Image Analyzer

Table 2 gives the results of a similar analysis of the standard grading pictures of the Japan Meat Grading Association using a image analyzer. All of the readings bore a relation to the degree of marbling, but there was a marked difference between the various grade levels when compared as a function of total area and aggregate value of the perimeters of the marbled fat seams. The total value for the area represents the absolute value for the amount of fat in the roast loin eye, and the aggregate perimeter of the marbled fat seams appears to be a good indicator of the fineness of the grain of the marbling. Thus, we came to the conclusion that the degree of marbling can be precisely quantitized through the use of an image analyzer. The percentage of total area that is marbled fat within the loin eye is shown in Table 3, with the +5 grade showing a value of a whop-ping 32.5% of the cross-section area being fat.

Through the use of either of the above methods, namely that of the use of either a spectrophotometer or an image analyzer, we were able to show that fat marbling could be quantified and a standard value given to the +0 to +5 grades used in evaluating loin eye on the meat market.

SETTING THE STANDARD VALUES FOR BEEF FAT MARBLING:

In previous section, we described the methods used to evaluate beef marbling and the results, that were obtained. From among these results, the values developed from the image analyzer for the percentage of total area of the eye that is fat and the fineness of the marbled fat grain that is indicated by the aggregate perimeter value were shown to be well suited for use as standard values for beef fat marbling. The measured values for the 6 standard pictures labeled +0 to +5 used by the Japan Meat Grading Association are shown in Table 3. Both the values for the percentage of the total area that is fat and the perimeter of the marbled area increase at more or less regular intervals as one goes from +0 to +5. Since the value of area ratio at +5 is 32.5%, if we assign a value of 0% to the +0 grade, that means that a completely regular increase in value would come to 6.5% per grade level. These values are shown in Table 4, and with the exception of the +0 ranking, the values conform closely with the actual observed values. Thus, we chose to use these values as the standard values for the ratios of marbled fat area in the cross-sections of loin eye of the +0 to +5 grades. Since the aggregate perimeter value for the +5 grade was 244 cm (Table 3), we rounded this off to 250 cm while at the same time, in keeping with the arbitrary 0% for fat content in the +0 grade, we wet the aggregate perimeter value at 0 cm. As is shown in Table 4, this gives a neat 50 cm increase for each grade, and it is these values that we chose for our standard values. In actuality, of course, a +0 grade will never have a totally 0 value, and so, as is indicated in Table 4, those samples with values considered in the range of 0 are graded +0.

CONSTRUCTION OF SIMULATION MODELS FOR BEEF FAT MARBLING:

The following process, as is illustrated in Fig. 3, was used in the construction of simulation models for beef fat marbling: (1) the standard grading pictures used by the Japan Meat Grading Association were used,with the film negatives blown up to approximate the actual size of a loin eye cross-section; (2) the pictures were reproduced while adjusting the light and dark contrast and were transferred onto plaster boards of about 1.5 cm in thickness; (3) the areas corresponding to the fat marbling seams were carved out in sharp outline to a considerable depth; (4) the excess plaster outside of the shape of each of the loin eye forms was removed; (5) these molds were then impressed into silicon resin to make female molds; (6) these were then used to form male molds using dental molding material (alginate); (7) in addition to the above process, a female mold complete with the texture of an actual specimen of loin eye was made with silicon resin; (8) this was modified to conform to the size of the loin eye pictures used in steps (1) - (6), and a male mold of the prescribed thickness was made with silicon resin; (9) soft polyester was used to make female molds corresponding with the male mold of (8); (10) next, using the male molds of(6), a silicon resin compound colored to resemble beef fat, and containing ethyrole, hardener, and hardening

accelerator was poured into the grooves of the molds; (11) the contents of these grooves, which correspond to the marbled fat seams, were then transferred to the female molds of (9) made of soft polyester; (12) around these, then, silicon resin colored to look like red meat was poured into the molds and hardened to form the final product (13).

During the beginning of our experimentation with standard simulation models, we made them in accordance with the 6 grade levels of +0 to +5 that were in use at that time, but since the distribution of grade levels on the actual meat market are, as is illustrated in Fig. 4, highly skewed towards the lower values, during our third trial, we added levels between the +0 and +3 grades of +0.5, +1.5, and +2.5 giving a set of 9 simulation models.

As our experimentation continued, we then increased the grade levels to the same 13 levels used in the meat color simulation model series with values of +0.5 to +6.5. Our next adjustment was to increase the number of levels to 19 by first taking the 9 models of our third trial and changing the numbers, going from the level with the least marbling, to 1, 1.5, 2, 2.5, 3, 3.5, 4, 5, and 6. Samples corresponding to less than 1 on the scale were labeled 0.5,while those above a 6 were labeled 6.5, and in between those levels,additional levels of 1.25, 1.75, 2.25, 2.75, 3.25, 3.75, 4.5, and 5.5 were also added yielding a total of 19 grade levels of beef fat marbling.

At this point, however, the new market standards adopted by the Japan Meat Graders Association came into play, and in order to conform to the new judging standards for fat marbling, we came out with a final product of a set of 12 graded simulation models using a numbering system of 0, 0^{+}, 1^{-}, 1, 1^{+}, 2^{-}, 2, 2^{+}, 3^{-}, 3, 4, and 5. Table 5 gives the model numbers together with the grading standard number for the degree of marbling, followed with their equivalent grades in the older systems.

For the purpose of grading actual meat samples by comparison with the simulation models, any cross-section of the longissimus thoracis will do, but the best results are obtained by using a cut of the loin eye between the 6th and 7th ribs. Likewise, when comparing meat from two or more head of cattle, it is important to use samples from the same part.

When preparing a sample for grading, it is important to use a side of beef that has been chilled, and then to expose the cut to the air for approximately one hour ("blooming"). Then, the sample can be laid along side the models under sufficient light (using a daylight lamp if natural lighting is insufficient) in order to grade it according to which of the models it most closely resembles.

THE ADAPTABILITY OF STANDARD SIMULATION MODELS FOR BEEF FAT MARBLING:

All tolled, 3 trial sets of simulation models for beef fat marbling were made. Each trial run began with the taking of pictures of meat samples, blowing those negatives up to a standard size, and then analyzing them with an image analyzer to see if the values obtained for the ratio of total area that is fat and the aggregate value for the perimeters of the marbled fat seams matched the standard values. The results are as is shown in Table 6. The first trial run of simulation models yielded values that were rather low when compared to the standard values, and since, with the exception of model No. 1, they were roughly 1/2 the standard values, the amount of marbling in the simulation models was significantly increased for the second trial run.

The values resulting from the second trial run were still slightly low when compared to the standard values, but were much closer than the first run. So at this point, we enlisted the help of professional graders from various markets to give us an evaluation. The general consensus of opinion was that we should use a standardized shape and size for the loin eye simulation models, that we should intensify the color of the red meat sections, and that we should add luster to the overall appearance. These recommendations were taken into account in the making of our third set of simulation models.

The results of the use of the third trial set of simulation models in an actual meat market setting are shown in Fig. 4, which shows the frequency distribution of the various grades for both Japanese Black and Holstein cattle. As the bar graph shows, the maximum values are concentrated in the grades with little marbling and thus, there is not a normal "bell-shaped" distribution. It is for this reason that we widened the scale for the lower numbered grades and added rankings between the +0 and +1, the +1 and +2, and the +2 and +3 rankings to give a set of 9 simulation models. The results were a set of simulation models whose total fat area and aggregate perimeter values matched very closely with the standard values. They were evaluated by professional graders and judged to match the standards very well with the exceptions of model numbers 3 and 4 being slightly low.

Next, we took the evaluations of the third trial set of models and, as is shown in Table 7, divided them up into 6 levels to be used as standards, and then added appropriate levels below 1, above 6 and at various points in between. These were then again evaluated on the meat market. The results of the comparison between the graders' grade levels and the judgements based on the use of the simulation models is shown in Fig. 5. There was a high correlation of 0.94 between the two, and data fit a linear regression curve quite well. These showed that the use of the third set of simulation models gives accurate and quick grade evaluations for both Holstein, with its relatively small amount of marbling, and Japanese Black, with its high degree of marbling.

The fourth trial set of 12 grade levels that is based on the new market standards is a refinement of the third trial run and it has now been made into the standard for grading beef fat marbling. A comprehensive evaluation of its application on the meat market is, however, not yet complete and is awaiting the collection of data after the new standards are fully implemented.

CONCLUSION: The standard marbling simulation models that we have described in this paper are made in a scientific, objective way, and thus can be reproduced in mass without dependence on subjective, sensory perception. It is for this reason that NAKAI et al.(1987, 1988) have taken out a U.S. Patent on this procedure and its application and on a similar set of simulation models for grading beef color. These standard simulation model sets for beef meat and fat, pork meat and fat, and beef marbling are already on the market, and we are now developing a similar thing for grading chicken meat.

REFERENCES:

NAKAI, H., IKEDA, T., ANDO, S. and OZUTSUMI, K. (1987): "Method of Making Standard Marbling Models Used for Judging and Grading Beef." U.S. Patent, 4,668,457 (May 26, 1987).

NAKAI, H., IKEDA, T., ANDO, S. and OZUTSUMI, K. (1988): "Method of Making Standard Color Models Used for Judging Beef." U.S. Patent, 4,731,209 (Mar. 15, 1988).

Table 1. Total peak areas(cm^2) and average values(cm^2) for scanning along the major and minor axes of loin eyes graded at +0 to +5.

	Degree of fat marbling					
	+0	+1	+2	+3	+4	+5
Total peak areas of line 1	5.3	4.6	9.7	12.3	15.0	17.2
Average value of line 1	0.4	0.4	0.5	0.8	0.7	1.1
Total peak areas of line 2	5.1	5.4	9.0	11.7	15.9	16.9
Average value of line 2	0.4	0.4	0.6	0.6	0.8	0.8
Total peak areas of line 3	6.3	7.8	11.6	15.0	15.6	21.4
Average value of line 3	0.4	0.5	0.7	0.9	0.7	1.2
Total peak areas of line 4	3.7	3.8	4.3	9.4	7.3	8.3
Average value of line 4	0.5	0.5	0.5	1.6	0.8	0.6
Total peak areas of line 5	2.8	6.8	3.4	5.0	8.2	4.5
Average value of line 5	0.5	0.9	0.3	0.6	0.7	0.6
Total peak areas of line 6	2.6	4.4	10.9	6.5	5.6	8.4
average value of line 6	0.3	0.3	1.0	0.7	0.6	0.8

Table 2. Total area of fat marbling, and aggregate values for the length, maximum width and perimeter of each of the marbled fat seams of loin eye determined from the use of an image analyzer on grading pictures of the Japan Meat Grading Association.

Grade	Area(cm^2)	Length(cm)	Width(cm)	Perimeter(cm)
+0				
+1	1.7	17.0	6.2	35.8
+2	3.2	25.0	8.2	54.0
+3	7.2	43.2	16.2	116.3
+4	10.1	47.8	22.4	145.0
+5	11.3	59.0	25.8	176.2
	15.0	63.9	29.5	244.1

Table 3. The ratio of fat to total loin eye cross-section area and the aggregate perimeter of the marbled fat seams for the standard pictures of the +0 to +5 grade values of the Japan Meat Grading Association as measured by an image analyzer (average and standard deviation of 5 measurements).

Grade	Ratio of marbled fat	Aggregate perimeter
+0	3.7±0.2(%)	35.8±2.3(cm)
+1	7.0±0.2	54.0±1.3
+2	15.6±0.7	116.3±7.7
+3	21.9±0.7	145.0±3.5
+4	24.4±1.1	176.2±9.1
+5	32.5±1.6	244.1±9.2

Table 4. The setting of standard values for grade levels according to ratio of marbled fat area to the total area and the aggregate perimeter value.

Grade	Ratio of marbled fat	Aggregate perimeter
+0	0 (%) (0 - 4%)	0 (cm) (0 - 40cm)
+1	6.5	50
+2	13.0	100
+3	19.5	150
+4	25.0	200
+5	32.5	250

Table 5. Relationship of the beef marbling simulation models and the traditional beef marbling evaluation standard to both the old and the new standard grades. The terms used in the old grade express similar meanings in English as follows: Nami-Fourth, Chu-Third, Jo-Second, Gokujo-First, Tokusen-Prime. In the new grade, such terms are simplified to Arabic numerals.

B.M.S.M.No.		No1	No2	No3	No4	No5	No6	No7	No8	No9	No10	No11	No12
Evaluation Standard		0	0^+	1^-	1	1^+	2^-	2	2^+	3^-	3	4	5
Classified Grade	New	1	2	3		4			5				
	Old	Nami			Chu			Jo			Gokujo	Tokusen	

Table 7. Numeralization of fat marbling in relation to the third set of simulation models for beef fat marbling.

Comparison relative to the model	Evaluation number
Below Model No.1	0.5
Corresponding to Model No.1	1
Between Model No.1 and 2	1.25
Corresponding to Model No.2	1.5
Between Model No.2 and 3	1.75
Corresponding to Model No.3	2
Between Model No.3 and 4	2.25
Corresponding to Model No.4	2.5
Between Model No.4 and 5	2.75
Corresponding to Model No.5	3
Between Model No.5 and 6	3.25
Corresponding to Model No.6	3.5
Between Model No.6 and 7	3.75
Corresponding to Model No.7	4
Between Model No.7 and 8	4.5
Corresponding to Model No.8	5
Between Model No.8 and 9	5.5
Corresponding to Model No.9	6
Over Model No.9	6.5

Table 6. Comparison between the standard values and the fat ratios used in the simulation models as was determined by analysis with an image analyzer.

Grade	Standard values	Trial 1	Trial 2	Trial 3
+0	0 (%)	1.8 (%)	2.6 (%)	0.8 (%)
+0.5				2.5
+1	6.5	3.5	6.7	6.2
+1.5				10.2
+2	13.0	6.1	15.1	15.3
+2.5				17.6
+3	19.5	11.1	17.8	24.4
+4	25.0	12.5	29.6	30.5
+5	32.5	16.0	30.3	32.9

Fig. 1. Scanning line positions along the major and minor axes of the loin eye cross-section at the 6th rib.

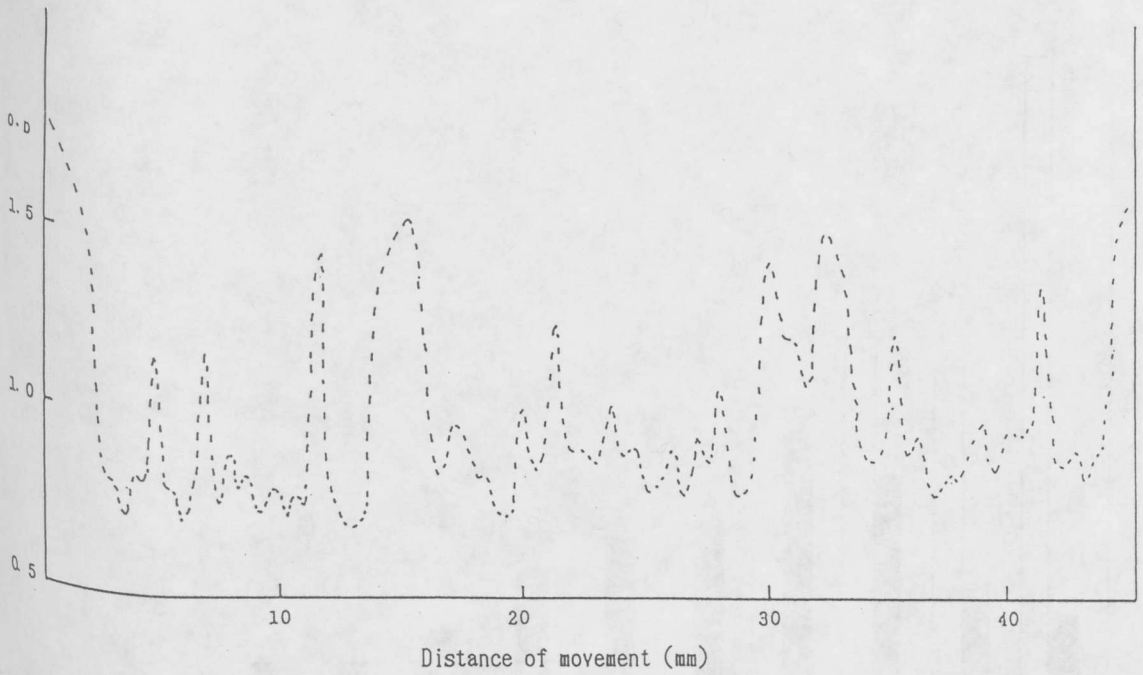

Fig. 2. Graph of light absorption at 563 nm measured with a Beckmann DU-8 spectrophotometer scanning the picture of a loin eye cross-section along its major axis. Each peak in the graph corresponds to a section of fat marbling, and thus by calculating the area of each peak, one can estimate the degree of marbling.

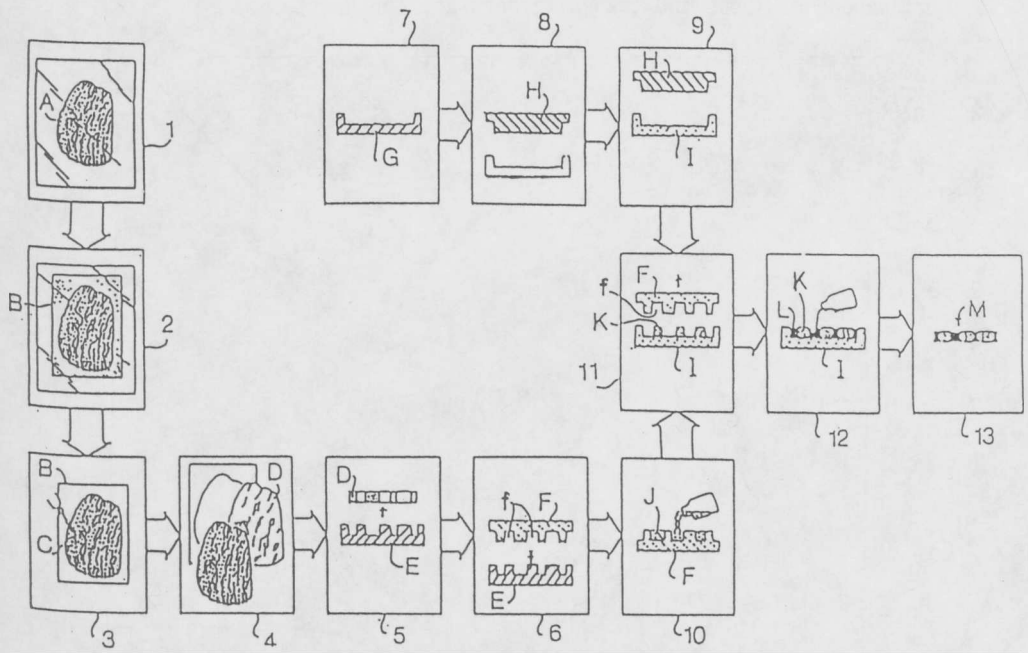

Fig. 3. Process used in the manufacture of beef marbling simulation models (refer to the main body of the manuscript for further details). A:picture used by the Japan Meat Grading Association; B:plaster board; C:carving out marbling pattern; D:cutting out the plaster board to the size of a loin eye; E:making female mold; F:making male mold G:female mold with texture of loin eye; H:making male mold; I:making female mold; J:making fat marbling sections; K: hardened sections of simulated fat; L:red meat sections; M:beef marbling simulation model.

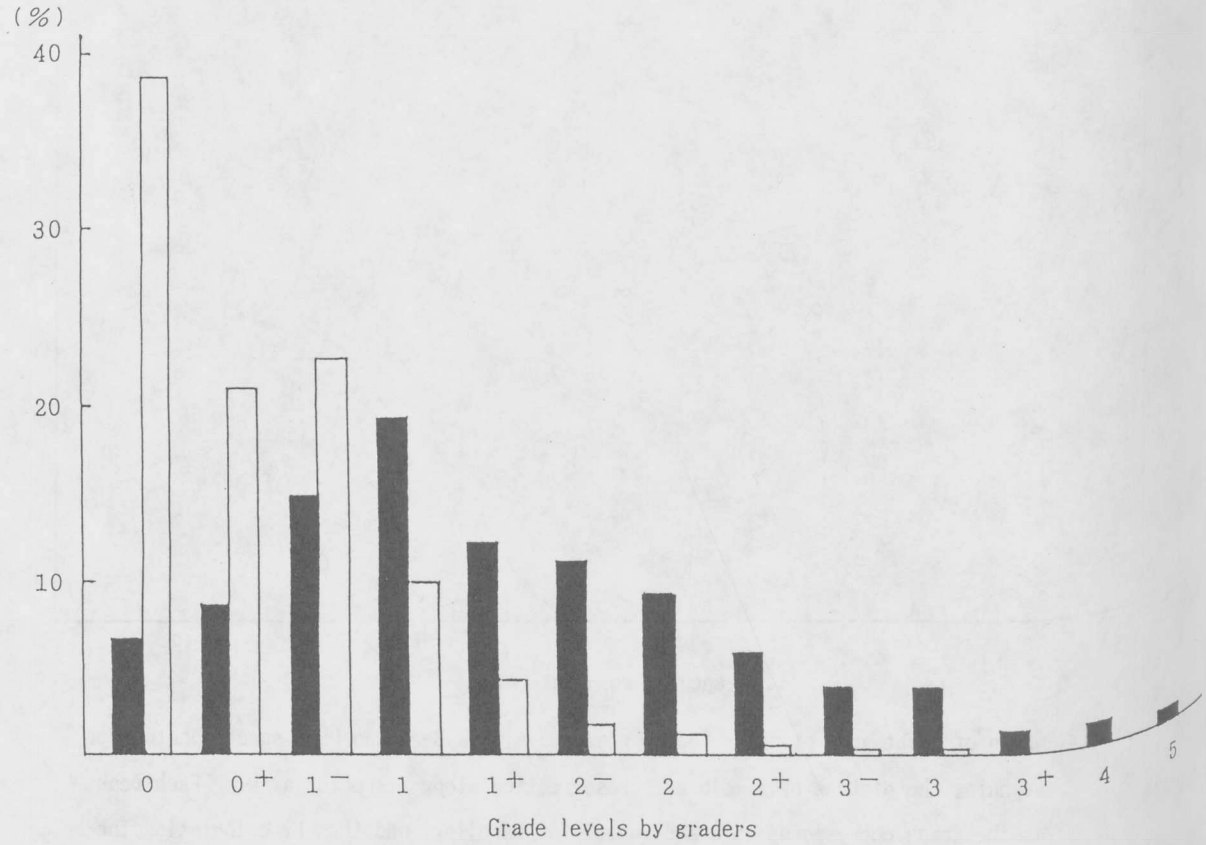

fig. 4. Frequency distribution graph of grade levels for sides of beef on the meat market for Holsteins and Japanese Black as graded by traditional method. The black bars are for Japanese Blacks and the white bars are for Holsteins.

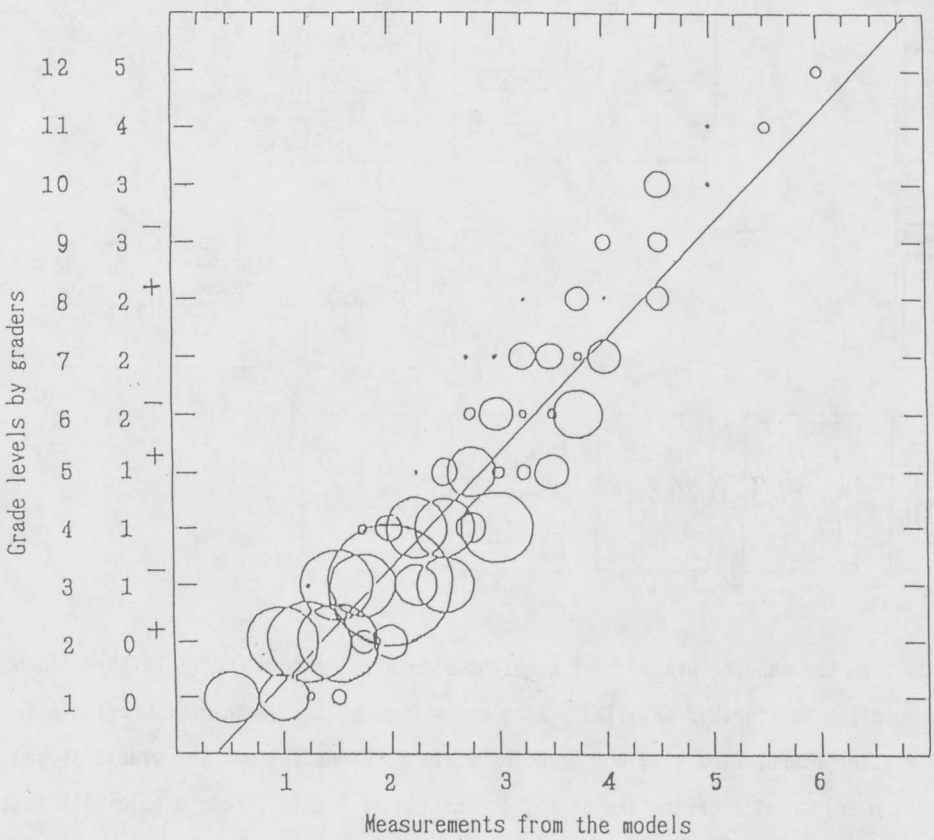

Fig. 5. Relationship between the grade levels assigned by graders and the levels determined from the use of the standard beef marbling simulation models (third trial run) when applied to 1500 Japanese Blacks and 490 Holsteins on the meat market.

$Y = 2.01X - 0.75$ $r = 0.941$