REFRACTIVE INDEX AS AN ESTIMATE OF QUALITY BETWEEN AND WITHIN MUSKMELON FRUITS[1,2]

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(WITH TWO FIGURES)

Introduction

Many difficulties arise in connection with testing the eating quality of fruits. Table quality depends on taste to a great extent, and uniform agreement among different individuals as to the desirability of certain flavors seems to be an elusive objective. An evaluation may be obtained by getting numerous estimates in quantitative classes and averaging them. This, however, is laborious and generally too tedious for extensive use. The present work on muskmelons arose in connection with varietal improvement studies with this crop. It was evident that a heterozygous population produced progenies with wide differences in quality that were traceable to quality differences in their parents. Inconsistencies in such observations, however, indicated the desirability of more accurate determinations of quality than was possible by having a few individuals taste the fruits and give them quality ratings. Use of the hand refractometer that is commonly used in rapid testing of sugar beet juice for sugar content appeared to offer a solution to the problem, provided it gave a reliable index to eating quality. This method has been used by different workers (**1, 2**) for testing melon quality but there has not appeared in the literature any information as to the degree of error that may be involved when quality is estimated by this method. The data which follow are intended to show mainly the mathematical relation between such refractometer readings and quality ratings when the latter is determined by a number of organoleptic tests and to compare the variation that was found in such tests with the variation in estimates based on refractometer readings.

Materials and methods

In the initial study, juice of 30 muskmelons was tested by means of a Zeiss hand refractometer, a rapid and simple test for total soluble solids contained in the juice. Whereas the index of refraction of a substance is the ratio of the sine of the angle of incidence to the sine of the angle of refraction, the

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scale of the Zeiss hand refractometer is graduated from 0 to 30 in percentage of dry substance in the solution. The indices of refraction for 0, 5, 10, 15, 20, 25 and 30 per cent. by weight of aqueous sucrose solutions at 20° C. are 1.3330, 1.3403, 1.3479, 1.3557, 1.3639, 1.3723, and 1.3811 respectively.

The strains represented were progenies of a single heterozygous plant with varying amounts of inbreeding and selection covering one to five generations. The pedigree of the original plant is not known, but it is certain from types segregated that honeydew entered into the parentage. The samples of juice for refractometer tests were taken from the central area of the fruits and the fruits were then rated for quality by 19 people. Five arbitrary classes were set up ranging from one to five, with one being the lowest class for eating quality and five being the highest. Only whole numbers were used by the testers in rating the fruits. The readings obtained were averaged for each of the fruits and this mean was used as the quality rating of the respective melon.

A second set of observations, somewhat similar but differing in certain details, was collected. Ten fruits taken at random from a field of mixed strains were tested by the refractometer, juice being taken from the central area of the fruits. The fruits were quartered by cutting them longitudinally and transversely, the longitudinal cut being made as nearly as possible parallel to the surface of the ground upon which the melon rested as it developed. Figure 1 illustrates the four sections and the identifying numbers. It is obvious that a larger number of fruits would have been desirable but it was thought that 40 samples was near the maximum number that could be properly tested by an individual at one time.

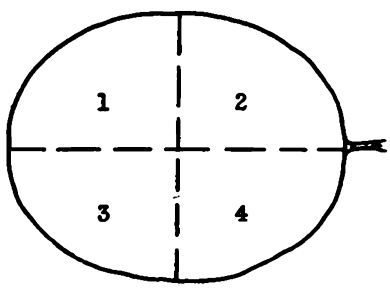

FIG. 1. The cuts made to divide muskmelon fruits into four sections and the respective numbers of the sections.

The 40 sections were each tested by the hand refractometer and laid out at random. Then eighteen persons tested, independently, each of the 40 samples and rated them for quality in classes ranging from one to five. This arrangement provides comparisons and tests of different parts of the fruits which were not possible in the original test.

Results

Data on quality from the initial test

The analysis of variance for the first test is summarized in table I. It is evident that fruits differed significantly in quality, and that the testers differed significantly in rating them. The F value exceeds the 1 per cent.

TABLE I

Analysis of variance of quality ratings on 30 muskmelon fruits

Source of variation	Degrees of freedom	Sum of squares	Mean square	F	Standard error
Melons	29	223.0	7.70	*	....
Testers	18	71.0	3.94	*	....
Error (melons × testers)	522	452.3	0.866	......	0.930
Total	569	746.3	....	......	....

* Exceeds 1 per cent. point.

point in both instances. The standard error of 0.930 indicates the high degree of variability that occurs from such a test. The standard error of the mean of 18 tests is $\frac{0.930}{\sqrt{18}}$ or 0.219 which is taken as the standard error of the melon means. A difference of approximately 0.620 between means is statistically significant and one of 0.850 is highly so. Calculations show that ratings by 7 testers would have been needed to establish the statistical significance of a difference of one class between two melons. This emphasizes the relationship of taste variations to measurement of quality differences. The relationship is more emphatic if the calculation is made to find the number of tests needed to establish statistical significance of a difference of 0.5 of a class. It is found that the standard error of the mean must reduce to 0.176 which would require approximately 28 observations.

The refractometer readings as shown in table 6 cover a wide range and undoubtedly represent melons of several distinct classes. The relation of these results to the quality ratings will be discussed more fully under the heading of correlation.

Data on quality from the second test

The possibility that the blossom end of a muskmelon is higher in quality than the stem end is frequently encountered and likewise it is possible that the top and bottom halves of the fruit differ in quality. In order to test these possibilities, the analysis of variance was made as summarized in table II. Since this analysis shows the sections to be significantly different, it is desired to compare the means for differences. Figure 2 A is a diagrammatic presentation of the quality means of the four sections. A difference of

TABLE II

ANALYSIS OF VARIANCE FOR QUALITY SCORES OF FOUR SECTIONS OF EACH OF 10 MUSKMELON FRUITS BASED ON INDIVIDUAL ESTIMATES OF 18 TESTERS

SOURCE OF VARIATION	DEGREES OF FREEDOM	SUM OF SQUARES	MEAN SQUARE	F	STANDARD ERROR
Testers	17	78.28	4.61	†	....
Melons	9	375.73	41.75	†	....
Sections	3	12.97	4.32	*	....
Melons × sections error (A)	27	37.84	1.40	†	1.18
Testers × melons	153	240.00	1.57	†	....
Error (B)	510	324.18	0.64	......	0.80
Total	719	1069.00	....	......	....

* Exceeds 5 per cent. point.
† Exceeds 1 per cent. point.

approximately 0.211 is significant and one of approximately 0.286 is highly significant. Therefore, although the difference is small, section 2 differs significantly from the other three sections but none of these differ among themselves by statistically significant amounts. It is apparent that quality ratings differed between halves of the fruits. The blossom end was slightly but significantly higher than the stem end, and the bottom half was insignificantly higher than the top half.

The means of the halves have a standard error of 0.062. These are also

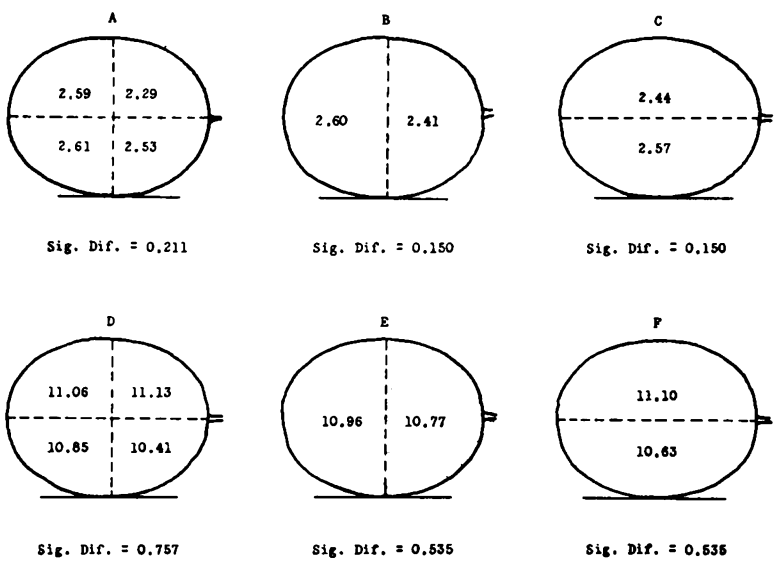

FIG. 2. Diagrammatic presentation of quality ratings A, B, and C and refractometer readings D, E, and F of different areas of muskmelon fruits.

shown diagrammatically in figures 2 B and 2 C. A difference of 0.150 between these is statistically significant and one of 0.202 is highly so. It is apparent that the two ends of the fruit show a difference that is significant. In the case of the upper and lower halves, the difference is smaller and does not reach the five per cent. point. The odds, however, are approximately 12:1 against a difference of this size being the result of random samples. The data definitely seem to suggest minor differences in quality between various parts of the fruits and therefore the desirability of defining areas when the fruits are tested for quality.

The interaction sums of squares, shown in table II, are of some interest. That of testers × melons, being significant, indicates that various testers rated the same melons differently. Stated otherwise, the quality of a melon may appeal to a certain tester but would rate low in the opinion of another. Thereby the point is illustrated that individual estimates vary as to what constitutes desirable or undesirable quality. The detailed results on this interaction are shown in table III. The differences in estimates may be readily seen by observing a typical case such as the ratings given melons A and I by testers 11 and 13.

TABLE III

THE QUALITY RATINGS OF 10 MUSKMELON FRUITS AS DETERMINED BY 18 TESTERS RATING FOUR SAMPLES OF EACH FRUIT

Tester	Melon										Mean
	A	B	C	D	E	F	G	H	I	J	
1	3.50	2.00	4.25	2.00	1.00	3.00	2.00	3.00	1.75	2.75	2.52
2	4.25	2.50	5.00	1.75	1.00	4.00	2.25	2.75	3.00	1.25	2.77
3	3.00	2.25	4.75	2.00	1.00	3.75	3.00	2.75	2.75	3.75	2.90
4	3.00	1.00	3.50	2.75	1.00	2.50	3.00	1.50	2.75	1.75	2.27
5	2.00	1.25	2.00	1.75	1.50	2.00	2.25	2.50	2.50	1.00	1.87
6	1.75	3.00	5.00	2.00	1.25	2.50	2.50	1.50	3.75	1.50	2.47
7	2.50	2.00	3.00	3.00	1.00	2.75	1.75	2.00	3.75	1.25	2.30
8	3.50	2.25	3.25	2.75	1.00	3.00	2.75	2.75	4.50	3.25	2.90
9	3.50	3.00	4.50	2.50	1.25	3.00	2.75	2.00	3.75	3.00	2.92
10	3.50	2.00	4.50	3.00	1.00	3.25	2.25	2.25	3.75	2.75	2.82
11	3.75	1.00	4.00	2.00	1.50	3.50	1.75	2.00	2.75	1.50	2.37
12	2.75	2.75	5.00	3.75	1.25	3.00	3.00	2.50	3.75	3.50	3.12
13	1.25	1.75	4.75	2.50	1.00	2.50	2.75	2.75	4.25	1.25	2.47
14	3.75	1.75	4.50	1.75	1.00	2.75	1.75	2.50	3.25	1.50	2.45
15	2.50	2.75	2.00	3.50	1.00	3.75	2.25	2.00	3.25	1.25	2.42
16	2.75	1.75	3.25	2.00	1.00	2.25	2.50	1.50	3.50	1.50	2.20
17	1.75	1.25	3.25	2.50	1.25	2.00	2.25	2.50	3.50	1.00	2.12
18	1.75	2.50	2.25	2.75	1.00	2.50	2.25	1.50	3.50	1.50	2.15
Mean	2.82	2.04	3.82	2.46	1.11	2.89	2.39	2.24	3.33	1.96	....

The melons × sections interaction was significantly greater than that for error (B). Table IV shows the data on this interaction. It is evident that considerable variation occurred in a certain section for different melons.

TABLE IV

QUALITY RATINGS FOR FOUR SECTIONS OF EACH OF 10 MUSKMELON FRUITS AS DETERMINED BY 18 TESTERS PER SAMPLE

MELON	SECTION OF MELON				MEAN
	1	2	3	4	
A	2.78	2.89	2.67	2.94	2.82
B	2.17	1.78	2.39	1.83	2.04
C	4.11	3.33	4.33	3.50	3.82
D	2.11	2.39	2.44	2.89	2.46
E	1.22	1.00	1.05	1.17	1.11
F	3.06	2.67	3.06	2.78	2.89
G	2.72	2.00	2.17	2.67	2.39
H	2.39	1.94	2.22	2.39	2.23
I	2.94	3.06	3.83	3.50	3.33
J	2.44	1.78	1.94	1.67	1.96
Mean	2.59	2.28	2.61	2.53	....

The interaction can be visualized by noting that section 1 had the highest rating in three of the fruits, section 2 in none of them, section 3 in three, and section 4 in two fruits. In two cases there was an equal rating between sections for the highest score; one and three in the case of fruit F, and one and four for fruit H. Thus, it is seen that although section 1 had the high score in most cases, section 3 had the highest general average, and that the section ratings differed in different melons.

CONSISTENCY OF EXPERIENCED TESTERS

Considering the variation in estimates by the organoleptic tests the question may arise as to the possibility of reducing this if the individuals making the ratings have had previous experience at it. It may be possible that extensive sampling would enable an individual to be more consistent in his ratings. Three of the samplers in the second test were individuals who had had considerable experience at testing various fruits and vegetables in research work. Attempting to determine the effect of this background on their comparative ratings, correlation coefficients were calculated between the mean melon ratings of each of these three and the mean of each melon for 12 of the other testers. The scores of the three remaining testers were also correlated with the scores of the 12 combined and were found to give essentially the same correlations as that for the experienced testers. It appears in this instance, that the experienced testers were not superior over three testers selected at random in estimating the mean of several tastes.

REFRACTOMETER DATA FROM THE SECOND TEST

When the 40 refractometer readings are divided and analyzed, as shown in table V, it is seen that statistical significance between sections is not indicated although the quality differences shown by figures 2 A, 2 B, and 2 C, are significant. This suggests that the quality score differences for different sec-

TABLE V

ANALYSIS OF VARIANCE FOR 40 REFRACTOMETER READINGS ON FOUR SECTIONS OF EACH OF 10 MELONS

Source of variation	Degrees of freedom	Sum of squares	Mean square	F	Standard error
Melons	9	217.25	24.14	*	....
Sections	3	4.24	1.41	......	....
Error	27	18.51	0.68	......	0.825
Total	39	240.78	....	......	....

* Exceeds 1 per cent. point.

tions were possibly the result of factors other than soluble solids, as indicated by the refractometer readings. TUCKER (4) has shown that the sugar content varies in different parts of a watermelon fruit. SCOTT and MACGILLIVRAY (3) obtained uniform readings in soluble solids for longitudinal sections of muskmelons but found an increasing gradient from the stem to the blossom end for cross sections. In the present study the odds for some of the comparisons, although not 20 : 1, are rather high. As example, section 3 compared with section 4 gives odds of 7 : 1; and the top half compared with the bottom half gives odds of approximately 15 : 1. It is of interest that these differences are not in the same relationship as the differences between the quality scores. This seems to be further evidence that the quality differences between sections may result from factors other than sugar content. From the above it is understandable that the analysis of covariance failed to show significant correlation between quality score and refractometer readings within fruits although it was quite definite between fruits.

CORRELATION DATA

The correlation coefficient for the first set of data calculated between the refractometer readings and the quality score means shown in table VI is + 0.636 and is highly significant. The regression of quality on refractometer reading is 0.167. This is the average amount by which the quality score varied with a unit change in refractometer reading. Using this regression coefficient and a refractometer reading, it is possible to estimate the quality score. The accuracy of the estimate is indicated by the last column in table VI. The standard error of estimate is 0.493, which may be considered as an average of the differences between observed and estimated quality. This is a decidedly lower value than the standard error of 0.930 shown in table I.

In the second test, having the correlation broken up, it is possible to consider the relationship for within melons and between melons by Fisher's

TABLE VI

REGRESSION OF QUALITY ON REFRACTOMETER READING FOR MUSKMELONS (QUALITY RATING IS THE MEAN AS DETERMINED BY THE ESTIMATES OF 19 INDIVIDUALS GIVING RATINGS OF 1 TO 5 FOR QUALITY)

FRUIT NO.	REFRACTOMETER READINGS	OBSERVED QUALITY	ESTIMATED QUALITY	OBSERVED – ESTIMATED
1	12.0	2.63	3.03	– 0.40
2	11.8	2.37	3.00	– 0.63
3	9.5	1.95	2.60	– 0.65
4	12.8	2.47	3.17	– 0.70
5	8.5	1.58	2.45	– 0.87
6	11.0	2.79	2.87	– 0.08
7	13.4	3.68	3.27	0.41
8	11.2	2.89	2.89	0.00
9	12.0	3.10	3.03	0.07
10	8.0	2.63	2.36	0.27
11	9.2	3.42	2.56	0.86
12	12.5	3.05	3.12	– 0.07
13	13.0	3.26	3.20	0.06
14	7.6	2.74	2.30	0.44
15	8.2	2.11	2.40	– 0.29
16	9.2	3.37	2.56	0.81
17	8.4	3.26	2.33	– 0.93
18	13.4	2.95	3.27	– 0.32
19	10.0	2.89	2.70	0.19
20	6.8	1.79	2.16	– 0.37
21	9.4	2.58	2.60	– 0.02
22	8.0	2.11	2.36	– 0.25
23	14.0	3.37	3.36	0.01
24	9.4	3.05	2.60	0.45
25	12.2	3.16	3.07	0.09
26	9.4	2.58	2.60	– 0.02
27	6.2	2.00	2.06	– 0.06
28	5.0	1.37	1.86	– 0.49
29	7.0	1.95	2.20	– 0.25
30	10.8	3.89	2.83	0.96

analysis of covariance method. A regression coefficient for between melons is arrived at as well as one for the association within melons or between sections. As previously stated, however, it was found that the correlation within fruits was not significant, and the correlation between refractometer reading and quality score mean for between fruits was essentially the same as that for total. Furthermore, the one refractometer reading originally taken on the 10 fruits when correlated with the quality means gave approximately the same value as that when the mean of four refractometer readings was used.

Inasmuch as this single reading approximates the results of the more extensive readings and represents considerable saving in time, it seems desirable to limit further analysis to the one reading data. The correlation coefficient between this value and quality score is + 0.862 and is highly significant. The regression of quality on refractometer reading is 0.264 in this instance. The weight in grams of the 10 melons also was correlated with quality, the value being + 0.655 and slightly above the five per cent. point. This is surprising and the relationship probably is not generally true of muskmelon fruits. Fruit size being a character easily measured, however, it should be more adequately studied in relation to quality between types as well as within uniform strains. The multiple correlation coefficient between the three measurements was found to be + 0.909. As shown by table VII, the standard error of estimate is 0.342. Based on this 10-melon sample, it is apparent that estimating quality from the multiple regression is relatively accurate.

TABLE VII

REGRESSION OF QUALITY SCORE ON FRUIT SIZE AND REFRACTOMETER READINGS FOR MUSKMELON FRUITS (QUALITY RATINGS DETERMINED BY 18 INDIVIDUALS MAKING FOUR TESTS PER FRUIT)

FRUIT IDENTIFICATION	WEIGHT IN GRAMS	REFRACTOMETER READING	OBSERVED QUALITY RATING	ESTIMATED QUALITY	DIFFERENCE
A	1490	10.4	2.81	2.22	0.59
B	1350	11.0	2.04	2.33	−0.29
C	3850	13.3	3.82	3.69	0.13
D	1290	12.2	2.45	2.63	−0.18
E	970	6.0	1.11	.90	0.21
F	2000	12.6	2.88	2.95	−0.07
G	2640	11.0	2.38	2.72	−0.34
H	1550	9.6	2.23	2.02	0.21
I	1380	13.8	3.33	3.08	0.25
J	1600	10.9	1.95	2.38	−0.43

Comparing the respective standard errors, it is noted that the above 0.342 is approximately equal to that of 12 testers sampling by tasting, since 1.18 divided by the square root of 11.9 approximately equals 0.342. Thus, it seems that the simple weight and refractometer tests were useful tools for calculating eating quality under the conditions of this test. The calculation for getting the estimated quality is 0.0003 times the weight in grams plus 0.264 times the refractometer reading and this sum minus 0.975. Although the calculation is a simple one, a melon breeder would seldom use it in testing selections. The simple procedure of comparing refractometer readings would suffice in most instances.

Summary and conclusions

Thirty muskmelons representing a mixture of types were tested for the percentage of soluble solids in the juice by means of a hand refractometer. The melons were then rated quantitatively in ascending classes from one to five by 19 people tasting them. Analysis of the data indicates that the melons were significantly variable in quality and that testers varied significantly, some tending to rate the fruits low and others to rate them high. The standard error of 0.930 illustrates the difficulty of satisfactorily

classifying the fruits by tasting unless the mean of a number of opinions is obtained. Ratings by three experienced testers did not approach the mean scores appreciably more closely than the ratings of three testers selected at random.

In a second test, 10 muskmelon fruits were cut into four sections after they were tested by the refractometer. Each section was tested separately by the refractometer and also rated for quality by 18 testers. The results indicate slight but significant differences in quality between different parts of the fruits. The blossom end averaged higher than the stem end. The bottom half was not significantly higher than the upper half. Interaction data show poor agreement among the different individuals in rating the fruits for quality. Also it is shown that certain sections were high in some melons and low in others. Analysis of the refractometer readings do not show statistically significant differences between the different parts of the fruits and such differences as did occur were somewhat opposed to the differences in quality. It is, therefore, suggested that the quality differences between sections may have resulted from factors other than those measured by the refractometer.

For the first set of data, quality rating estimates based on the regression of quality on refractometer readings gave an error of estimate appreciably lower than the standard error by tasting. A correlation coefficient of + 0.636 and a regression coefficient of 0.167 were found. In the second lot of data, there was positive correlation between fruit weight and quality score (+ 0.655) as well as between refractometer reading and quality score (+ 0.862). Using multiple regression the error of estimate was further reduced so that it approximately equals the standard error of the mean of 12 samplers. The coefficient of correlation for the three characters is + 0.909. The information on the relation between fruit size and quality is thought to be incomplete but the extent to which refractometer readings can be used in estimating muskmelon quality is considered well demonstrated by the foregoing material.

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