QUALITY OF GRADED EGGS

at Four Grading Plants

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SUMMARY

Various grades and weight classes of shell eggs were sampled each week for a 56-week period at four commercial egg grading plants. Individual eggs within each sample carton were measured for interior quality by means of the Haugh unit (an objective index of interior egg quality) and examined for shell and internal defects. Within plants, statistically significant differences in Haugh unit averages were found between weight classes within grades, between grades of the same weight class, and between the same grades in different seasons of the year. This was true for both white eggs and brown eggs. Differences ranged from about 2 to 6 Haugh units and, with a few exceptions, were less than 8 Haugh units. The latter value was used as a criterion for determining important differences in interior quality.

A comparison of the distributions of the Haugh unit scores of defect-free eggs into the four Haugh unit ranges corresponding to the U. S. Department of Agriculture quality standards showed very small differences between the grades sampled at each plant. In all plants, 90 percent or more of the defect-free eggs of each candled grade were of A quality or better. Thus, large percentages of A quality eggs were found in Grades B and C as well as in Grade AA, indicating the difficulty of segregating, by candling, eggs which are relatively uniform and high in quality.

Grades AA and A were practically free of eggs with gross shell defects; that is, misshapen, stained, "dirties," and "checks." This indicates that the requirements for shell quality in these grades in the Federal standards are met without difficulty.

Relatively low incidences of eggs with blood and meat spots were found in all grades. With few exceptions, the higher grades contained fewer eggs with spots than did the lower grades. Eggs with small spots (1/8 inch and less in diameter) were found in greater numbers than were eggs with large spots. In all grades, the incidence of eggs with spots was higher among brown eggs than among white eggs.

The significance of these results in the light of recent developments in egg grading is discussed in this report.

BACKGROUND AND PURPOSE

Studies of the relationship between appearance, when candled, and the quality of shell eggs, have been reported by a number of investigators (1, 2, 3, 17, 21-27)[2]. Reports of studies dealing with the accuracy of candlers have also been published (6, 14, 18, 19, 20). All these studies support the view that candling is not a highly accurate method for evaluating interior quality of new-laid eggs.

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[1] Mr. Davis has resigned from AMS.

[2] Underlined numbers in parenthesis refer to items in Literature Cited, p. 13.

Because eggs which enter present-day market channels are generally higher and more uniform in quality than those marketed a few decades ago, the necessity of candling each egg individually to assign grades to consumer dozen-egg lots has been questioned. A proposed substitute is to grade by objectively measuring the quality of a statistical sample of eggs produced and handled under conditions which minimize the deterioration of initial quality. A plan employing this approach has recently been inaugurated on a voluntary basis by the U. S. Department of Agriculture (12, 28). Determination of interior quality on such a basis, together with the use of multiple candling to detect and reject defective eggs, has proved to be effective (8, 9, 12).

Few data are available regarding the effectiveness of present-day commercial grading, by candling, of eggs received directly from farms; that is, "fresh" eggs. Such information is of value to producers, packers, and consumers of shell eggs, to government officials concerned with promulgation of standards of egg quality, and to researchers involved in developing improved egg grading techniques. This research project was designed to provide such information.

PLANS AND PROCEDURES

Because most eggs sold at retail move directly from producers to central receiving and distribution plants and are candled for quality there, a realistic evaluation of commercial grading of "fresh" eggs by candling may be obtained by determining the quality of graded eggs at this level. Accordingly, data were collected in four commercial egg grading plants during about 56 weeks. Each plant was in a different section of the United States, and was typical of those in its area.

Four experienced candlers in each plant were selected to grade the eggs received from each of four producers who were known to practice good methods of producing and handling eggs. The candlers graded the eggs, alternating week to week, according to the following plan:

	Egg Grading Plan			
	WHITE EGGS supplied by:		BROWN EGGS supplied by:	
	Producer #1	Producer #2	Producer #3	Producer #4
	Graded by:		Graded by:	
1 day, 1st wk.	Candler "a"	Candler "b"	Candler "c"	Candler "d"
Same day, 2nd wk.	" "b"	" "a"	" "d"	" "c"
" ", 3rd wk	" "a"	" "b"	" "c"	" "d"
" ", 4th wk.	" "b"	" "a"	" "d"	" "c"
etc.	etc.	etc.	etc.	etc.

Brown eggs were not packed in plant 3. The same general plan was followed, however, with two of the four candlers grading white eggs from two different producers, alternating week to week in the manner shown, and two candlers alternately grading eggs from two other producers of white eggs.

Each week, one carton of eggs of each grade and weight class was picked from each of the selected candler stations. Each egg within the carton was then removed, examined carefully for shell defects, weighed to the nearest ounce per dozen on a commercial egg scale, and then broken out onto a flat, transparent glass plate. With the aid of a mirror on the underside of the plate, the egg was examined for the presence of blood or meat spots as well as other interior defects. The size of blood and meat spots was recorded as greater than 1/8 inch in diameter or 1/8 inch in diameter and less. The interior

quality of each egg was then determined by measuring Haugh units (10) with the aid of an egg quality slide rule (13).

The Haugh unit is an objective index of the interior quality of the egg, based on the weight of the intact egg and the height of the albumen when the egg is broken out on a flat surface.

Determinations were made by a specially trained employee of the plant and were completed within 2 hours after the eggs were graded.

All information was recorded on specially prepared forms and later transferred to data processing cards for tabulation and analysis.

This study was based on determinations made on a total of 31,404 white eggs and 15,348 brown eggs. Approximately 1,200 eggs of each shell color, candled grade, and weight class category were examined in each of the plants, except plant 3 where approximately 2,100 per category were examined. Grades and weight classes that were not packed every week are not included in this report.

RESULTS AND DISCUSSION

Interior Quality of Various Candled Grades and Weight Classes of Shell Eggs

The Haugh unit averages of the various grades and weight classes of eggs examined in each of the four plants are shown in table 1. These averages are based on the Haugh unit scores of all eggs within each category sampled throughout this study. Factors other than interior quality as evaluated by candling, therefore, may have determined the grade. An analysis of variance of the Haugh unit scores of eggs examined in each plant revealed a number of differences among these averages which were statistically significant at the 5 percent level of probability. The differences between adjacent weight classes within grades ranged from 0.4 to 5.4, with an average difference of 2.8 Haugh units for white eggs, and from 1.2 to 3.6, with an average of 2.2 Haugh units, for brown eggs. The differences between the Haugh unit averages of Extra Large and Medium within grades of white eggs ranged from 2.0 to 4.5 with an average of 3.3 Haugh units. The difference between these two weight classes of brown eggs in plant 1 was 3 Haugh units.

Comparisons among the averages indicated that there was a marked tendency for Haugh unit averages within grades to vary inversely with weight. With only two exceptions, the Haugh unit averages of Medium eggs were higher than those of Large or Extra Large eggs. Large eggs in every instance had a higher Haugh unit average than Extra Large eggs within the same grade.

With few exceptions, the average Haugh units declined from the higher to the lower candled grades within each weight class. Differences ranged from 2.0 to 10.4, with an average of 5.5 Haugh units for white eggs, and from 1.8 to 3.1, with an average of 2.2 units for brown eggs.

The largest differences between grades were among the white eggs sampled in plants 2 and 3, although only one valid comparison could be made in plant 2, that is, between Large AA and Large A.

The analyses of variance also indicated that the grade Haugh unit averages varied among different periods of the year. The Haugh unit averages of Large eggs of the various candled grades for a 7-week period in each of the seasons of the year are given in table 2. This variation was probably due to a number of factors, including the ages and strains of the flocks involved, as well as to the seasonal variations in temperature and humidity. Despite the variation, however, the pattern of differences between grades generally paralleled that seen in the overall averages for each plant.

TABLE 1.--Haugh unit averages of various grades[1] and weight classes of commercial shell eggs examined in 4 egg grading plants

Color, candled grade, and weight class	Plant 1	Plant 2	Plant 3	Plant 4
	Haugh units	Haugh units	Haugh units	Haugh units
WHITE				
AA:				
Extra Large	69.3 cd[2]	----	----	----
Large	----	87.2 c	79.1 e	68.7 c
Medium	----	----	81.8 f	----
A:				
Extra Large	65.8 b	----	72.9 e	----
Large	68.1 c	77.2a	75.5 c	66.0a
Medium	70.3 d	82.6 b	74.9 d	68.4 b
B:				
Extra Large	62.9a	----	62.5a	----
Large	66.1 b	----	66.3 b	65.3a
Medium	----	----	----	----
C:				
Large	62.2a	----	----	----
BROWN[3]				
AA:				
Extra Large	71.0 d	----	----	----
Large	----	----	----	71.3 c
Medium	----	----	----	----
A:				
Extra Large	69.2 bc	----	----	----
Large	70.8 cd	81.6 b	----	68.2a
Medium	72.2 d	80.4a	----	71.8 c
B:				
Extra Large	67.4a	----	----	----
Large	69.2 bc	----	----	68.5ab
Medium	----	----	----	----
C:				
Large	68.2ab	----	----	----

[1] Candled grade not determined by interior quality alone.
[2] For each shell color, averages within a column followed by the same letter or letters are not significantly different at 5% level.
[3] No brown eggs packed in plant 3.

The practical importance of these differences can be evaluated by considering the relationship between Haugh units and the interior quality of eggs which meet the requirements for the four candled qualities (AA, A, B, and C) as set down in the United States standards (28). Brant and others (5) showed that this relationship was essentially linear and that eggs could be classed as AA, A, B, or C quality on the basis of Haugh unit scores. The four Haugh unit ranges corresponding to these qualities were: AA, 79 and

TABLE 2.--Haugh unit averages of various candled grades[1] of Large shell eggs examined in egg grading plants in different seasons of the year

Plant, candled grade	WHITE				BROWN[2]			
	Spring[3]	Summer[4]	Fall[5]	Winter[6]	Spring[3]	Summer[4]	Fall[5]	Winter[6]
	Haugh units	Haugh units	Haugh units	Haugh units	Haugh units	Haugh units	Haugh units	Haugh units
Plant 1								
AA	----	----	----	----	----	----	----	----
A	71.6	63.0	69.0	67.7	74.6	63.0	70.2	70.8
B	68.5	64.0	67.5	66.0	72.6	65.1	69.0	70.3
C	65.2	63.7	61.9	59.1	72.3	66.4	66.1	70.2
LSD[7]	1.5				1.8			
Plant 2								
AA	88.8	86.9	85.0	89.4	----	----	----	----
A	76.5	80.2	75.9	78.1	78.9	84.0	79.5	84.3
B	----	----	----	----	----	----	----	----
C	----	----	----	----	----	----	----	----
LSD	1.2				1.6			
Plant 3								
AA	79.9	78.6	78.2	80.3	----	----	----	----
A	75.9	72.2	73.4	72.9	----	----	----	----
B	69.6	65.4	65.1	65.4	----	----	----	----
C	----	----	----	----	----	----	----	----
LSD	2.0				---			
Plant 4								
AA	69.2	68.8	75.2	70.8	67.2	68.8	75.2	72.7
A	71.7	64.3	64.7	68.2	62.4	64.3	71.3	75.5
B	71.0	66.4	63.5	65.8	63.7	64.2	71.7	73.5
C	----	----	----	----	----	----	----	----
LSD	1.3				2.0			

[1] Candled grade not determined by interior quality alone.
[2] No brown eggs packed in plant 3.
[3] Spring - 7-week period ending on May 20.
[4] Summer - 7-week period ending on August 26.
[5] Fall - 7-week period ending on December 2.
[6] Winter - 7-week period ending on March 9.
[7] LSD - Least Significant Difference. Applies to differences between seasons for the same grade.

above;[3] A, 55 to 78; B, 31 to 54; C, 30 and below. Within each of these groups, eggs may be further classified into "High," "Medium," or "Low" quality, depending on whether they have Haugh unit scores in the upper, middle, or lower portions of the range, respectively.

This relationship implies that differences in the appearance of two opened eggs can be detected only if such eggs differ by a minimum of 8 Haugh units, although it is extremely doubtful that even this difference can be detected by the average consumer.

Using this value as a criterion, it is evident that the differences in Haugh unit averages between the various categories were, for the most part, too small to be of any

[3] Now 72 and above.

practical significance. Thus, in no case was the difference between weight classes within a grade greater than 8 Haugh units. Differences between adjacent grades of the same weight class exceeded 8 Haugh units in only two instances. These were between Large AA and Large A white eggs in plant 2 and between Extra Large A and Extra Large B white eggs in plant 3, which were 10.0 and 10.4 Haugh units, respectively. The only other large differences were between Grade AA and Grade B white eggs in plant 3 and between Medium Grade A and Large Grade C white eggs in plant 1. The differences in Haugh unit averages between seasons of the year for Large eggs of the various grades (table 2) were of the order of 2 to 6 Haugh units, indicating that the interior quality of eggs being received by the plants from the selected producers did not vary to any marked degree throughout the year.

These analyses indicate that differences in Haugh unit averages between various candled grades of eggs at the first receiving station are probably very small in terms of broken-out appearance quality, and may often be no larger than differences existing between weight classes of the same grade.

Because defects (if detected by the candler) may cause an egg to be downgraded, an evaluation of grades as indexes of interior quality should consider only eggs within the grades which are free of such defects, since it can then be assumed that these eggs were graded on the basis of interior quality alone. For this purpose, Haugh unit averages of the various grades and weight classes were recalculated using the scores of only defect-free eggs. These are presented in table 3. For ease of comparison, the Haugh unit averages in table 1 also are shown. It is evident that the omission of the Haugh unit scores of defective eggs did not markedly affect the averages.

A more meaningful and practical appraisal of the relation of candled grade to interior quality may be obtained from figure 1, which shows the distribution of the defect-free eggs within each of the grades into the Haugh unit ranges corresponding to the four quality classes. In constructing these charts, weight classes were not considered.

An examination of these charts reveals that, in all plants, 90 percent or more of the eggs in cartons labeled Grade A were of A quality or better on the basis of Haugh units. However, exceptionally large percentages of eggs of such high interior quality may also be noted in Grades B and C. Grade AA, except for plant 2, contained large numbers of eggs which were classed as A quality. Thus, if one compares Grades AA, A, and B in those plants in which all three of these grades were packed (plants 1, 3, and 4 for white eggs; plants 1 and 4 for brown eggs), it is evident that the interior quality distributions are similar.

It should be remembered that this study was carried out in packing plants. If measurements had been made at the retail level, the proportion of Grades B and C eggs falling into the respective ranges would probably have been somewhat greater. The proportion of Grade A eggs falling into the A quality range, however, would probably not have been greatly different from that shown, since the number of eggs dropping from A to B quality in this grade would have been offset by the number falling from AA to A quality, assuming that the rates of deterioration were about the same. Grade AA, however, would probably have contained fewer eggs above 79 Haugh units at the retail level. In effect, although the distribution patterns would not have been greatly changed, they would have been nearer the lower quality end of the Haugh unit scale. The degree of this displacement, of course, would depend on the time which had elapsed between grading in the plants and sampling at the retail level, as well as other factors.

These charts indicate that candling as a means of segregating fresh shell eggs according to interior quality is extremely difficult. This is true especially if eggs being graded do not vary greatly in this respect, as may be expected with the more controlled and improved conditions of production and handling of eggs on many present-day farms.

TABLE 3.--Comparison of Haugh unit averages of all eggs and of only defect-free[1] eggs of various grade-weight classes of eggs examined in 4 egg grading plants

Color, candled grade, and weight class	Haugh unit averages							
	Plant 1		Plant 2		Plant 3		Plant 4	
	All eggs	Defect[1] free	All eggs	Defect[1] free	All eggs	Defect[1] free	All eggs	Defect[1] free
WHITE								
AA:								
Extra Large	69.3	69.3	----	----	----	----	----	----
Large	----	----	87.2	86.9	79.1	79.1	68.7	68.7
Medium	----	----	----	----	81.8	81.8	----	----
A:								
Extra Large	65.8	65.8	----	----	72.9	72.9	----	----
Large	68.1	68.1	77.2	76.9	72.5	72.5	66.0	65.9
Medium	70.3	70.3	82.6	83.5	74.9	74.9	68.4	68.2
B:								
Extra Large	62.9	63.0	----	----	62.5	60.7	----	----
Large	66.1	66.4	----	----	66.3	64.0	65.3	65.1
Medium	----	----	----	----	----	----	----	----
C:								
Large	64.5	62.5	----	----	----	----	----	----
BROWN[2]								
AA:								
Extra Large	71.0	71.0	----	----	----	----	----	----
Large	----	----	----	----	----	----	71.3	71.4
Medium	----	----	----	----	----	----	----	----
A:								
Extra Large	69.2	69.3	----	----	----	----	----	----
Large	70.8	70.7	81.6	81.8	----	----	68.2	68.2
Medium	72.2	72.1	80.4	80.7	----	----	71.8	71.7
B:								
Extra Large	67.4	67.2	----	----	----	----	----	----
Large	69.2	68.7	----	----	----	----	68.5	69.1
Medium	----	----	----	----	----	----	----	----
C:								
Large	68.2	67.6	----	----	----	----	----	----

[1] Eggs without shell defects, blood or meat spots.
[2] No brown eggs packed in plant 3.

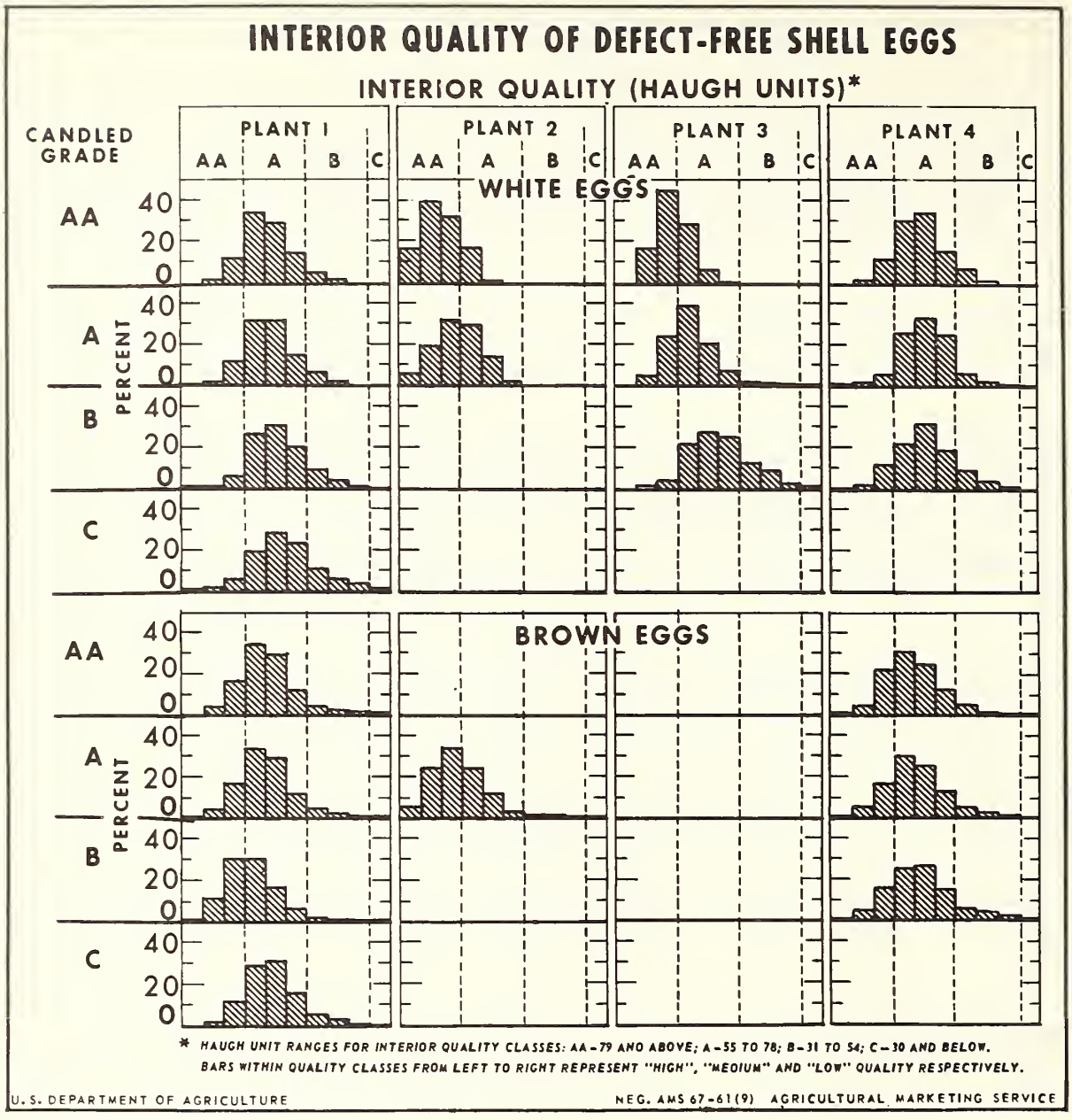

FIGURE 1.

Incidence of Defective Eggs Among Candled Grades

The only defects that occurred in sufficient number to warrant consideration were blood and meat spots, misshapen and stained shells, "dirties," and "checks." The number of eggs with other defects, such as mottled yolks, bloody albumen, and rots, was negligible in all plants. In this report, no distinction is made between blood and meat spots, nor between different degrees of staining or of abnormality in shape of shells.

The percentages of eggs with various types of shell defects are presented in table 4. The United States Standards for Quality of Individual Shell Eggs (28) do not permit any of these defects in eggs of AA or A quality. Eggs of B quality may be slightly abnormal in shape or slightly stained, whereas C quality eggs may be abnormal in shape and moderately stained. Dirty eggs or "checks" may not be assigned a letter quality. That the

Grade AA or Grade A samples taken in this study were practically free of shell defects indicates that commercial candlers have little or no difficulty in detecting these defects. The percentages of eggs with these defects in the B and C grades were not great.

The incidences of eggs with blood or meat spots in the various grades are presented in table 5. According to Federal standards (28), eggs with spots greater than 1/8 inch in diameter may not be classed as AA, A, B, or C quality, Eggs with smaller spots, however, may be classed as C quality.

TABLE 4.--Eggs with shell defects in various candled grades of shell eggs in 4 egg grading plants

Color, plant, and candled grade	Eggs examined	SHELL DEFECT			
		Misshapen	Stained	Dirty	Check
WHITE	Number	Percent	Percent	Percent	Percent
Plant 1					
AA	1164	< 0.1	<0.1	< 0.1	< 0.1
A	3516	< 0.1	<0.1	< 0.1	< 0.1
B	2364	10.9	8.0	< 0.1	<0.1
C	1104	19.9	9.8	0.6	6.0
Plant 2					
AA	1260	<0.1	<0.1	< 0.1	< 0.1
A	2484	<0.1	<0.1	< 0.1	< 0.1
B	----	----	----	----	----
C	----	----	----	----	----
Plant 3					
AA	4248	<0.1	<0.1	< 0.1	<0.1
A	6276	<0.1	<0.1	<0.1	<0.1
B	4224	35.7	4.0	<0.1	<0.1
C	----	----	----	----	----
Plant 4					
AA	1200	<0.1	< 0.1	< 0.1	< 0.1
A	2364	<0.1	< 0.1	< 0.1	< 0.1
B	1236	3.1	0.2	<0.1	< 0.1
C	----	----	----	----	----
BROWN					
Plant 1					
AA	1164	<0.1	<0.1	< 0.1	<0.1
A	3528	<0.1	<0.1	< 0.1	<0.1
B	2340	6.2	3.9	0.1	<0.1
C	1140	7.9	7.3	1.2	3.8
Plant 2					
AA	----	----	----	----	----
A	2472	<0.1	<0.1	< 0.1	<0.1
B	----	----	----	----	----
C	----	----	----	----	----
Plant 3[1]	----	----	----	----	----
Plant 4					
AA	1188	<0.1	<0.1	<0.1	<0.1
A	2400	<0.1	<0.1	<0.1	<0.1
B	1116	11.4	1.3	0.2	<0.1
C	----	----	----	----	----

[1] No brown eggs packed in plant 3.

TABLE 5.--Eggs containing blood or meat spots in various candled grades of shell eggs in 4 egg grading plants

Color, plant, and candled grade	Eggs examined	Size of blood or meat spot	
		1/8 inch diameter or less	Greater than 1/8 inch diameter
WHITE	Number	Percent	Percent
Plant 1			
AA	1164	0.4	< 0.1
A	3516	0.6	< 0.1
B	2364	1.0	0.1
C	1104	1.3	0.3
Plant 2			
AA	1260	3.3	< 0.1
A	2484	3.3	< 0.1
B	----	----	----
C	----	----	----
Plant 3			
AA	4248	0.5	< 0.1
A	6276	0.9	0.2
B	4224	1.4	0.1
C	----	----	----
Plant 4			
AA	1200	1.8	0.1
A	2364	2.3	0.3
B	1236	3.6	0.9
C	----	----	----
BROWN			
Plant 1			
AA	1164	11.3	0.3
A	3528	9.0	1.1
B	2340	12.0	1.8
C	1140	14.7	7.4
Plant 2			
AA	----	----	----
A	2472	5.8	< 0.1
B	----	----	----
C	----	----	----
Plant 3[1]	----	----	----
Plant 4			
AA	1188	8.4	2.6
A	2400	9.4	2.4
B	1116	10.9	3.2
C	----	----	----

[1] No brown eggs packed in plant 3.

Reports from other investigators have indicated that the accuracy of detection of eggs with spots ranges from about 28 to 100 percent, depending on the size (11) and location of the spot (7), age, and shell color of eggs (11). A recent study (6) conducted in an egg-handling plant under normal operating conditions showed candler accuracy in detecting blood spots (over 1/8 inch in diameter) in white eggs to be about 33 percent. In this same study, the corresponding value for flash candling was about 50 percent.

Our data indicate that spots 1/8 inch in diameter or less are more difficult to detect than larger spots, and that the incidence of eggs with spots is greater in candled brown eggs than in white eggs. The latter fact is probably a reflection both of greater incidence in brown eggs before they are candled (4) and greater difficulty for the candler in detecting the spots within the darker shelled eggs (15).

In view of the data presented in this report and the fact that other techniques are available, such as objectively measuring the interior quality of a statistical sample of eggs, supplemented with multiple candling and use of electronic devices, it seems prudent for packing plant operators to seriously consider adopting these techniques for grading eggs. It is evident from this study that if eggs are relatively uniform and high in interior quality, the accuracy of grading them by candling is of a low order. That new methods are feasible has been shown in a number of reports (8, 9, 29). Where eggs of greatly varying quality are to be graded, however, individual candling can and should continue to serve a useful function, at least until a nondestructive and commercially feasible objective method for grading individual shell eggs is developed.

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