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PROJECT NO.: 84-LB11-Tree and Crop Research

PROJECT TITLE: QUALITY IN RELATION TO MARKETABILITY OF ALMOND VARIETIES[1]

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OBJECTIVES:

(1) Evaluate differences in the various almond quality attributes and identify the traits that determine their suitability for particular market uses. (2) Develop appropriate methods for obtaining and analyzing data which can be used to evaluate the effects of genetic, environmental, and postharvest handling on almond market quality. (3) Apply these methods to compare quality among specific almond varieties and identify the most suitable marketing outlet(s) for each.

SUMMARY:

Physical, chemical and sensory methods were used to evaluate the quality attributes of 23 almond varieties as in-shell, raw natural, roasted, and blanched nuts. Average kernel weight ranged between 0.9g (Padre) and 1.5g (Ne Plus Ultra). Kernel width varied from 10.3mm (Solano) to 14.2mm (Tokyo). Most varieties had an average kernel thickness of 8 to 9 mm, but 'LeGrand' was the thickest (10mm) and 'Tokyo' was the thinnest (7.4mm). Several size/shape indices were developed.

'Sonora', 'Jeffries', 'Nonpareil', and 'Solano' were notably lighter and more yellow in skin color than other varieties. 'Mission', 'Padre', and 'Ruby' were the darkest. Textural differences were found among varieties. Genotypic variation in ease of blanching was noted with 'Mission' and 'Fritz' being the most difficult and 'Tokyo', 'Livingston', 'Merced', and 'Mono' the easiest. Blanched 'Yosemite' had the whitest color and 'Merced' was the least white.

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[2]On sabbatic leave from the University of Hawaii.

Genotypic variation in total fat and total sugars contents were noted among the 23 varieties tested. Total fat content ranged from 49% in 'Price' to 56.5% in 'Monterey'. 'Padre' contained the highest total sugars (6.0%) while 'Ne Plus Ultra' had only 4.1% total sugars.

Only small differences in sweetness were observed with 'Mission' and 'Monterey' being the sweetest. On the other hand, large differences in almond flavor intensity were found with 'Carmel', 'Mission', 'Livingston', 'Sauret I', and 'Sauret II' being highest and 'Butte', 'Price', and 'Yosemite' being lowest. Both firmness and crispness varied widely and were related to differences in moisture content. Roasted almonds were slightly less sweet and firm, but more crisp than raw almonds and lost the characteristic almond flavor. Sweetness and almond flavor intensity were positively correlated in both raw and roasted almonds.

On the basis of shell integrity, suture opening, and shell hardness, the most suitable varieties for in-shell marketing are: 'Mission', 'Padre', and 'Peerless'. For marketing as raw or roasted natural kernels, the best varieties are: 'Jeffries', 'LeGrand', 'Livingston', 'Nonpareil', 'Ruby', 'Sauret I', 'Solano', 'Sonora', and 'Thompson'. Mixing of kernels among these varieties during marketing depends on similarity in kernel size, shape, and color.

Ease of blanching and color of the blanched kernel indicate that the most suitable varieties for marketing as blanched kernels are: 'Butte', 'Jeffries', 'Livingston', 'Merced', 'Mono', 'Nonpareil', 'Sauret I', 'Sonora', and 'Thompson'. Varieties that are suitable for slicing and slivering include 'Carmel', 'Nonpareil', and 'Sauret I'.

A quality evaluation procedure which can be used for advanced breeding lines which have passed the test for yield and preharvest factors and for recently introduced varieties which have not been adequately evaluated should include the following characteristics: absence of off-flavors and bitter taste, shell integrity and tightness, shell hardness and color, kernel susceptibility to cracking damage, kernel defects, kernel color and dimensions, kernel wrinkling and fuzziness, and ease of blanching and color of the blanched kernel.

INTRODUCTION:

The major varieties currently planted in California include Nonpareil, Mission, Merced, Ne Plus Ultra, Thompson, and Peerless. Many other almond varieties have been and continue to be introduced through the breeding programs of the University of California and private plant breeders. Orchard performance of many of these varieties is being evaluated in a series of Regional Variety Trial Plots throughout the main almond production areas of California.

Several categories or groups of almond varieties for marketing purposes are used by the California industry including: Nonpareil group (multiple uses), Mission group (roasted, unblanched kernels), California group (blanched kernels), Ne Plus Ultra group (elongated kernels used for planning or covering with a candy glaze), and Peerless group (in-shell use).

During the past few years, some of the newer varieties have been evaluated from the marketing potential standpoint. In 1980, a preliminary variety evaluation index was published (Kester et al, California Agriculture 34(10):4-7) which defined 40 characteristics into four categories: A) tree characteristics, B) tree and nut resistances, C) nut characteristics - raw product, and D) nut characteristics - processed product. Scores were given to five standard varieties (Nonpareil, Merced, Mission, Peerless, and Ne Plus Ultra) and six new varieties (Butte, Carmel, Fritz, Price, Ruby, Thompson). In July, 1983, a panel was convened to evaluate 10 additional varieties for categories C and D. This was followed by another industry panel evaluation of 24 varieties. These studies indicated that it is not only useful but essential to evaluate all new varieties as to their characteristics which influence marketing potential. Also, it became clear that the evaluation procedures needed further refinement and simplification so that they can be used annually for evaluating new varieties and testing the effects of environmental conditions on quality characteristics.

The objectives of this study were to determine which quality characteristics are important for each form of marketing (e.g. in shell, raw kernel, blanched kernel) and to develop an evaluation procedure that can be used by plant breeders and others in testing new varieties as to their postharvest quality and marketing potential.

MATERIALS AND METHODS:

A. Materials

Twenty to forty pounds of each of twenty-three varieties of almonds were harvested from the Regional Variety Trials (RVT) at Delta College in Manteca (15 varieties), Kern County (6 varieties) and the West Side Field Station (1 variety). The nuts were harvested in September and October 1984 and were brought to the U.C. campus where they were dried and hulled. With the exception of nuts held for in-shell evaluation, all the nuts were cracked by the California Almond Growers Exchange. The kernels were placed in cold storage at 0°C (32°F) in jars under a flow of nitrogen gas with a relative humidity of about 60% to achieve an equilibrium moisture content of 4% in the kernels.

B. In-Shell Nut Evaluation

1. Shell Integrity. From a sample of 125 nuts, a subsample was drawn consisting of 3 replications of 10 nuts each. Surface integrity of each nut was rated using a 5-point scale based on the percentage of the outer shell remaining intact as follows: 1 = 0 to 10%, 2 = 11 to 50%, 3 = 51 to 75%, 4 = 76 to 95%, 5 = 96 to 100%. Suture integrity was rated for each nut as follows: 1 = open, 2 = closed.

2. Shell Color. A second subsample of 3 replications of 10 nuts was drawn for several objective measurements. Shell color was measured on a Gardner XL-23 Tristimulus Colorimeter using a 10mm aperture. Rd (lightness), a (redness), and b (yellowness) values were determined.

3. Shell Hardness. On these same nuts, shell hardness was measured with the U.C. Fruit Firmness Tester fitted with a 1.6mm (1/16 in.) probe. The force measured was that required to penetrate the inner shell.

4. Weight. On the same nuts both in-shell and kernel weights were taken and from these, kernel yield was calculated.

C. Raw Natural Kernel Evaluation

1. Pellicle Wrinkling. A photographic standard (Fig. 1) was used for rating the degree of pellicle wrinkling of 30 randomly selected nuts of each variety. Kernels with no wrinkling were rated 1 and those with extreme wrinkling were rated 5. Each kernel was cut in half cross-wise and the cross-section was evaluated.

2. Fuzziness. An additional 30 kernels of each variety were selected to rate the degree of fuzziness of the kernel surface with 1 being smooth, no fuzziness and 5 being extremely fuzzy.

3. Defects. From a sample of 100 nuts, the percentage of doubles, twins, broken, blanks, navel orangeworm damaged, twig borer damaged and other defect nuts was determined.

4. Size and Shape. The width, length and thickness (maximum, at 3mm from bottom, and at 4mm from top) of a randomly selected sample of 30 kernels of each variety were measured. Kernel weights were also determined.

5. Color. Surface color (Rd, a, b) of these same kernels was measured by the Gardner Colorimeter.

6. Hardness. Still using the same kernels, hardness of each kernel was measured using the Food Technology Corporation Texture Testing System fitted with the shear blade attachment. The 300-lb. transducer was used with an operating speed of 30 sec. Maximum force (i.e. force to cut through the kernel) was recorded.

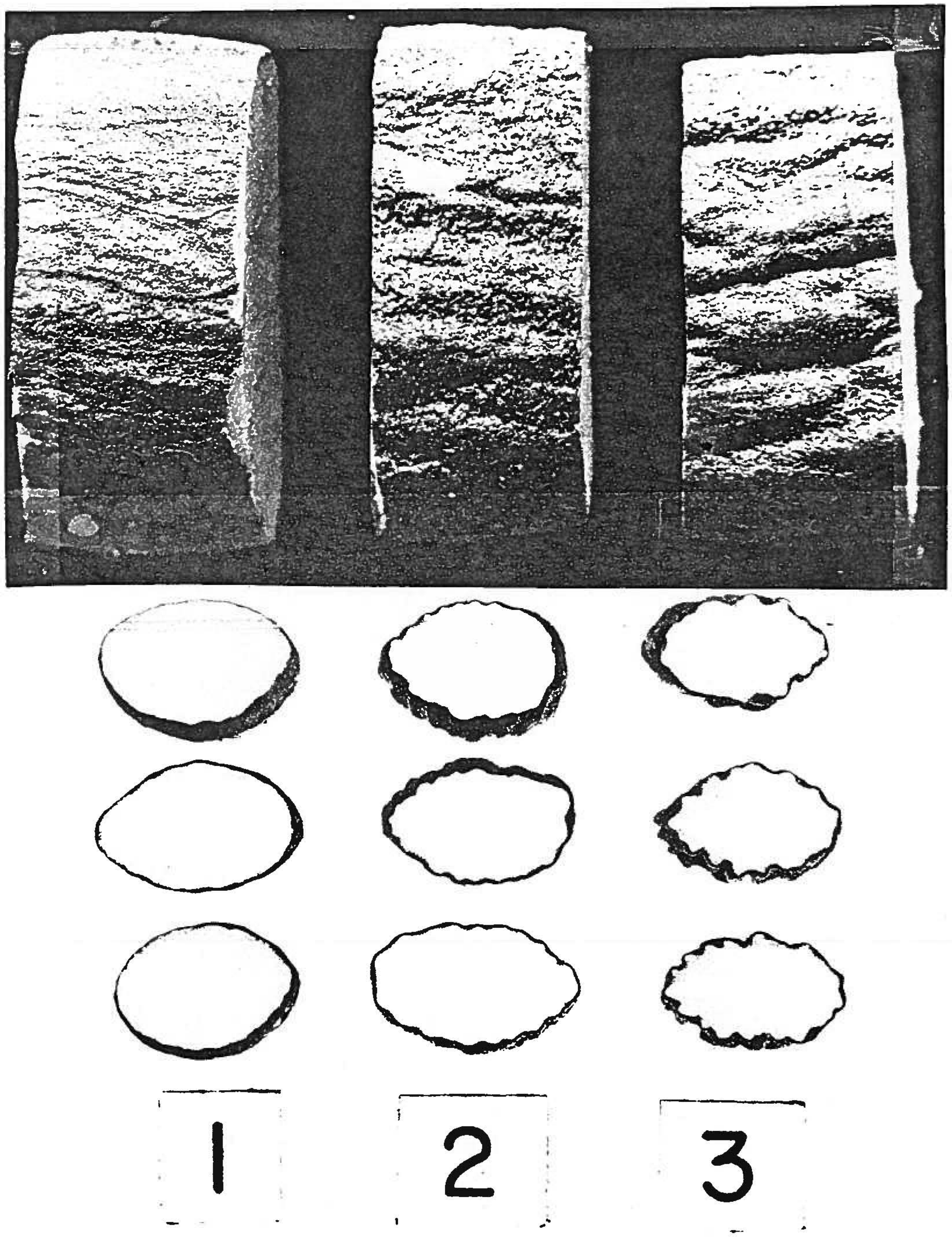

Figure 1. Photographic standard used for rating the degree of pellicle wrinkling.

7. Resistance to Mechanical Damage. After cracking, the entire lot of each variety was assessed for damage caused during cracking. Damage took the form of pellicle abrasion, chips, splits and broken kernels. Each variety was rated on a scale from 1 (poor resistance, high damage) to 5 (high resistance, low damage).

8. Sensory Evaluation. A panel of 11 subjects was trained for 5 days to evaluate the following characteristics:

Sweetness: sensation typified by the taste of sugars
Almond flavor intensity: overall strength of all flavor characteristics combined
Off-flavor: a flavor not usually associated with fresh almonds; usually a musty, old flavor. Other off-flavors may include rancidity or a burnt flavor
Firmness: force required to penetrate nuts upon first bite with the molar teeth
Crispness: brittle, friable nut texture

Each characteristic was rated on a 10-cm line with the ends labeled "none" and "extreme" and the subjects were instructed to place a mark on the appropriate point on the line. The measurements were later converted to scores on a 10-point scale. Tasting was done in individual taste booths equipped with red lighting to mask color differences. Six varieties were randomly selected each day and each variety was replicated 3 times for a total of 33 observations per variety. Individual samples consisted of 3 nuts/variety and were served in random order in containers coded with random 3-digit numbers. All varieties were evaluated except LeGrand which had some mold contamination. Judges were instructed not to swallow the samples.

9. Chemical Analyses.

a. Moisture: Three replicates of 20 grams each were weighed before and after drying in a vacuum oven at 70°C and 24mm Hg of vacuum to a constant weight and moisture content was calculated.

b. Fat: Dried kernels were ground in a coffee grinder and 5-g samples of meal were placed into cellulose fiber extraction thimbles. These thimbles were placed into a reflux fat extractor and each sample was extracted into 50 ml ethyl ether for 5 hours. Then the ether was evaporated in a stream of filtered air before weighing to determine the percent of ether-extractable fats.

c. Total Sugars: After extraction of oil, the dry residue was extracted with 80% ethanol (the extract contained the soluble carbohydrates. Total sugars were anlayzed by the colorimetric phenol method. Two ml of the extract were pipetted into a tube and 0.1 ml of 80% phenol was added followed by 5 ml of concentrated sulfuric acid. The tubes were placed in a water bath at 30°C for 15 min. The light absorbance was measured at 490 nm and total sugars percent was determined from a standard curve.

D. Roasted Kernel Evaluation

1. Roasting Procedure. One hundred fifty kernels of each variety were dry-roasted in Farberware convection ovens at the California Almond Growers Exchange. Roasting temperature was 149°C (300°F). Roasting time was governed by color and ranged from 21 to 37 min. A medium roast was achieved by this procedure. No salt or other coating was applied.

2. Sensory Evaluation. The procedure used for raw natural kernels was also used for roasted kernels.

3. Moisture Analysis. Moisture content was determined as for raw kernels.

E. Blanched Kernel Evaluation

1. Blanching Procedure. Approximately 200g of nuts that were free of significant chips and breakage were randomly selected. These nuts were placed in 1400 ml. boiling water and stirred constantly over gentle heat for 3 min. After one min., water temperature was recorded. In all cases, the blanching temperature was between 86 and 88°C (186 and 190°F). The nuts were then drained and held under a stream of cold water for 15 sec. Blanching proceeded by hand by squeezing the kernel out of its skin through the apical end.

2. Evaluation of Blanching Process. The number of splits and doubles was recorded as well as the number of "stickers", those that required extra effort to deskin and would be likely to leave some skin attached in production blanching. Samples were rated on overall difficulty of blanching (1 = easy, 10 = hard), skin thickness (1 = thin, 10 = thick), and swelling of skin/looseness of skin after cooling (1 = much swelling, 10 = little swelling).

3. Color. After air drying for 2 days, a subsample of 3 replications of 10 kernels was drawn for color measurement by the Gardner Colorimeter. Rd, a and b values were measured as well as the Whiteness Index (WI) and Yellowness Index (YI).

F. Statistical Analysis

Analysis of the data was done by computer using SAS (Statistical Analysis System) and included the General Linear Models Procedure, mean separation by Least Significant Difference (L.S.D.), and correlation.

RESULTS AND DISCUSSION:

Results presented here are from nuts produced in a single year and, for each variety, from a single location. It is well-known that many environmental factors will influence the quality of almonds and for that reason, decisions on the suitability of a given variety cannot be based on a single set of data. However, the objective of this study was to relate certain nut characteristics to market quality and to define those characteristics in terms of suitability for certain market classes. Thus, although a given variety may vary from year to year or location to location, it may be placed in a given category at a given time based on its characteristics in a given year or location. Based on these results, a systematic evaluation should be continued in coming years to determine variability and to permit a more valid basis for recommendations.

Table 1 summarizes the characteristics thought to be important for different marketing classes. These characteristics are addressed below. Complete data are included in the Appendix.

A. In-Shell Evaluation

1. Shell Integrity. Results of the surface integrity evaluation are shown in Table 2. Surface integrity is an important characteristic for almonds to be sold in-shell. Only very minor abrasion during hulling is acceptable. Butte, Carmel, Fritz, Mission, Nonpareil, Peerless, Ruby, Solano and Thompson were satisfactory in this regard. Genotypic variation in suture integrity is shown in Table 3. Open sutures pose a particular problem in terms of navel orangeworm infestation and for this reason are undesirable. They can also be an avenue for other types of contamination such as other insects, bacteria, fungi, and other foreign substances. Only Mission, Padre and Peerless were free of open sutures, although Thompson had very few nuts with open suture.

2. Shell Color. Objective color results are shown in Fig. 2. Nuts that had the most outer shell intact were selected for color measurement. However in the case of Monterey which had a high percentage of outer shell removed, the measurements sometimes included portions of the inner shell. Those shells that were lighter were more yellow in color compared with those darker shells that were more reddish. Yosemite was lightest in color, followed by Peerless, Ruby, Ne Plus Ultra and Solano. Carmel, Sauret I, Price and Monterey were darkest.

3. Shell Hardness. The force to penetrate the shell relfects the strength of the inner shell since the outer shell requires a relatively smaller amount of force. Results are shown in Table 4. Mission, Peerless and Tokyo had the hardest shells. From the standpoint of in-shell marketing such a hard shell is desirable; those with thinner shells are more easily cracked in the production of kernels.

4. In-Shell Weight and Kernel Yield. Table 5 reports the weight and yield data for the 23 varieties. These weights are affected to a certain extent by the degree of shell surface integrity. The in-shell weight for Monterey is somewhat low because its surface integrity rating (1.5) indicated that most of the outer shell was removed in hulling. Nonetheless, these weights are probably indicative of the actual weights realized in production. In-shell weights ranged from 1.4g (Jeffries) to 3.2g (Peerless). Mission, Ne Plus Ultra, Tokyo and Peerless were the largest and Jeffries, Butte, Merced, Price, Sauret I and Solano were the smallest. With some exceptions, high in-shell weight is associated with low kernel yield. Of the largest varieties Ne Plus Ultra and Tokyo would be unlikely candidates for in-shell marketing due to poor shell surface

Table 1. IMPORTANT MARKETING CHARACTERISTICS FOR ALMONDS

	Marketing Outlet				
PHYSICAL CHARACTERISTICS	In-Shell	Raw Natural	Roasted	Blanched	Slivered & Sliced
Shell					
Size	x				
Hardness	x	x			
Color	x				
Absence of Defects	x				
Uniformity	x				
Kernel					
Size	x	x	x	x	x
Shape		x	x	x	x
Skin Smoothness		x	x		
Color		x	x	x	x
Uniformity		x	x	x	x
Absence of Defects	x	x	x	x	x
PROCESSING CHARACTERISTICS					
Resistance to Mechanical Damage	x	x	x		
Easily Cracked		x	x	x	
High Kernel Yield		x	x	x	
Salt & Flavoring Adherence			x		
Kernel Whiteness				x	x
Ease of Blanching				x	x
Ease of Slicing or Slivering					x
Yield of Sliced or Slivered Product					x
SENSORY CHARACTERISTICS					
Almond Flavor	x	x	x	x	x
Roasted Flavor			x		
Sweetness	x	x	x	x	x
Firmness	x	x	x	x	
Crispness	x	x	x	x	
Absence of Off-Flavor	x	x	x	x	x

Table 2. CLASSIFICATION OF ALMOND VARIETIES ACCORDING TO THEIR SHELL SURFACE INTEGRITY

Surface Integrity Score	Intactness (% of Outer Shell)	Varieties
4.1 - 5.0	> 95	Butte, Carmel, Fritz, Mission, Nonpareil, Peerless, Ruby, Solano, Thompson
3.1 - 4.0	76 - 95	Livingston, Merced, Mono, Ne Plus Ultra, Padre, Price, Sauret I, Sauret II, Sonora, Tokyo
2.1 - 3.0	51 - 75	Jeffries, LeGrand, Yosemite
< 2.1	< 51	Monterey

Table 3. CLASSIFICATION OF ALMOND VARIETIES ACCORDING TO THEIR SHELL SUTURE INTEGRITY (DEGREE OF OPENNESS)

Suture Integrity Score	Percent of Nuts with Open Sutures	Varieties
2.0	0	Mission, Padre, Peerless
1.9	7	Thompson
1.8	17 - 23	Butte, Fritz, Mono, Monterey, Ruby
1.7	27 - 30	Nonpareil, Yosemite
1.6	37 - 40	Sauret II, Solano
<1.6	> 40	Carmel, Jeffries, LeGrand, Livingston, Merced, Ne Plus Ultra, Price, Sauret I, Sonora, Tokyo

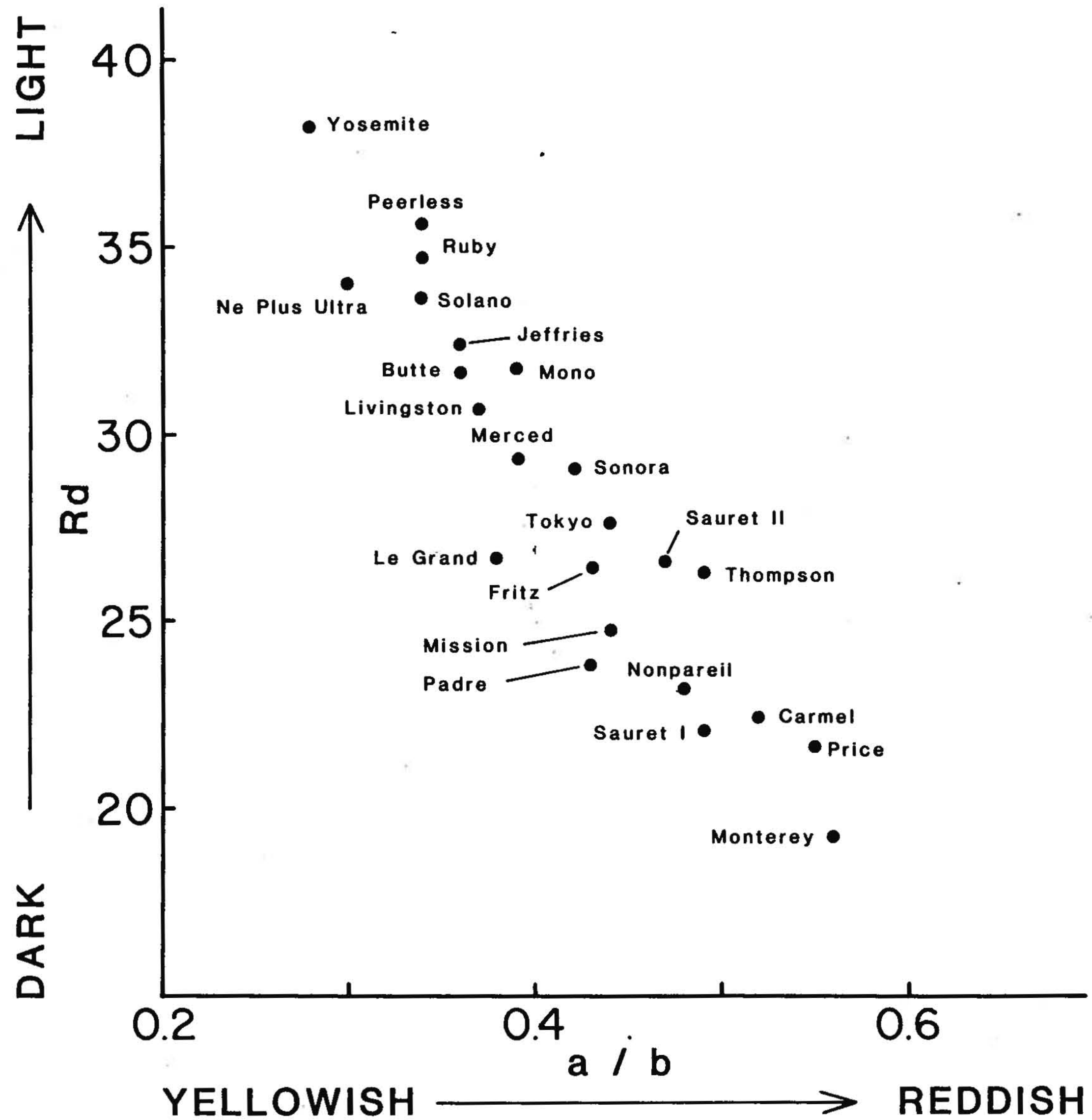

Figure 2. Genotypic variation in shell color as indicated by Gardner Color Difference Meter's Rd (degree of whiteness or darkness) and a/b ratio (degree of redness/yellowness) values.

Table 4. CLASSIFICATION OF ALMOND VARIETIES ACCORDING TO THEIR SHELL HARDNESS

Shell Hardness	Pounds of Force Required to Penetrate Shell	Varieties
Extra-hard	> 17	Mission, Peerless, Tokyo
Very Hard	15.0 - 16.9	Monterey
Hard	13.0 - 14.9	Fritz, Mono, Padre, Ruby, Yosemite
Intermediate	9.0 - 10.9	Butte, Carmel, LeGrand, Ne Plus Ultra, Sauret II
Soft	7.0 - 8.9	Jeffries, Livingston, Merced, Nonpareil, Price, Sauret I, Solano, Sonora, Thompson

Table 5. CLASSIFICATION OF ALMOND VARIETIES ACCORDING TO THEIR IN-SHELL WEIGHT. KERNEL YIELD (PERCENT EDIBLE PORTION) IS SHOWN IN PARENTHESIS FOLLOWING EACH VARIETY

In-Shell Weight (g)	Varieties
1.4	Jeffries (71)
1.5 - 1.6	Butte (67), Merced (75), Price (75), Sauret I (80), Solano (67)
1.7 - 1.8	Fritz (57), LeGrand (71), Livingston (67), Nonpareil (76), Padre (53), Sonora (76), Thompson (65), Yosemite (56)
1.9 - 2.0	Carmel (68), Ruby (55)
2.1 - 2.2	Mono (52), Monterey (59), Sauret II (67)
2.5 - 2.6	Mission (49)
2.7 - 2.8	Ne Plus Ultra (67), Tokyo (48)
3.1 - 3.2	Peerless (44)

integrity. Mission would be less desirable than Peerless due to dark shell color that might require bleaching.

C. Raw Natural Kernel Evaluation

1. Size/Shape. Kernel size and shape are critical factors in determining appropriate market classes. In addition, uniformity of size and shape is desirable. Other than the in-shell class discussed previously, almonds may be marketed as raw natural; dry-roasted natural; oil-roasted natural; flavored-roasted natural; sliced, slivered or diced natural; blanched whole; sliced, slivered or diced blanched. Fig. 3 shows the shape of the 23 varieties in relation to each other. A wide range is seen from long and narrow (Sauret II, Solano, Sonora) to short and wide (LeGrand, Mission, Padre, Tokyo, Ruby). Ruby, Jeffries, Tokyo and Thompson are the thinnest (7.4 to 7.6mm) and LeGrand the thickest (10mm).

For slicing and slivering, large, flat kernels are desired to achieve the maximum number of large whole slices with a minimum of wastage. Therefore, kernels with uniform thickness the length of the kernel are most desirable. Kernels that are too thin will result in a disproportionate number of "end" slices with pellicle when raw natural kernels are sliced. Fig. 4 shows some of the desirable and undesirable shapes for cutting.

To determine suitability for slicing and slivering, four criteria were developed: 1) the difference between the thickness measurements 3mm from the bottom and 4mm from the top should be less than 2.0mm, 2) maximum kernel thickness should be 8.0mm or greater, 3) the difference between maximum thickness and bottom thickness should be 2.0mm or less, 4) kernel length should be 21mm or greater. Those varieties that met all four criteria were Carmel, Non Pareil and Sauret I.

Weight is another important component of the size/shape factor. The average weights for the 23 varieties ranged from 0.9g/kernel (32 nuts/oz.) for Padre to 1.5g/kernel (19 nuts/oz) for Ne Plus Ultra (Table 6). Although weight is important in distinguishing large from small kernels, it is the distribution of that weight that is usually more important in determining kernel use.

2. Defects. Table 7 shows the defects found in each variety. Some of these defects are so serious that the value of the crop may be drastically reduced. Double kernels are misshapen and therefore unsuitable for use as a salted nut or for slicing. Although a small percentage can be tolerated, significant amounts are undesirable. Splits likewise will reduce the value of the crop since these are not suitable for salted nuts, blanching or for slicing. Deformities such a assymmetric or dimpled kernels are less aesthetically pleasing than well-formed kernels and are limited in use. Twins are especially a problem in kernels that will be blanched or sliced. Shrivels can constitute a major loss if a significant amount is present. Beyond a moderate degree of shriveling, the kernel may be totally useless. A high percentage of doubles were found in Ne Plus Ultra, Peerless, Price and Sauret II and were present in significant amounts in Livingston and Monterey. Splits were an extreme problem in Padre, serious in LeGrand, and significant in Ne Plus Ultra, Fritz, and

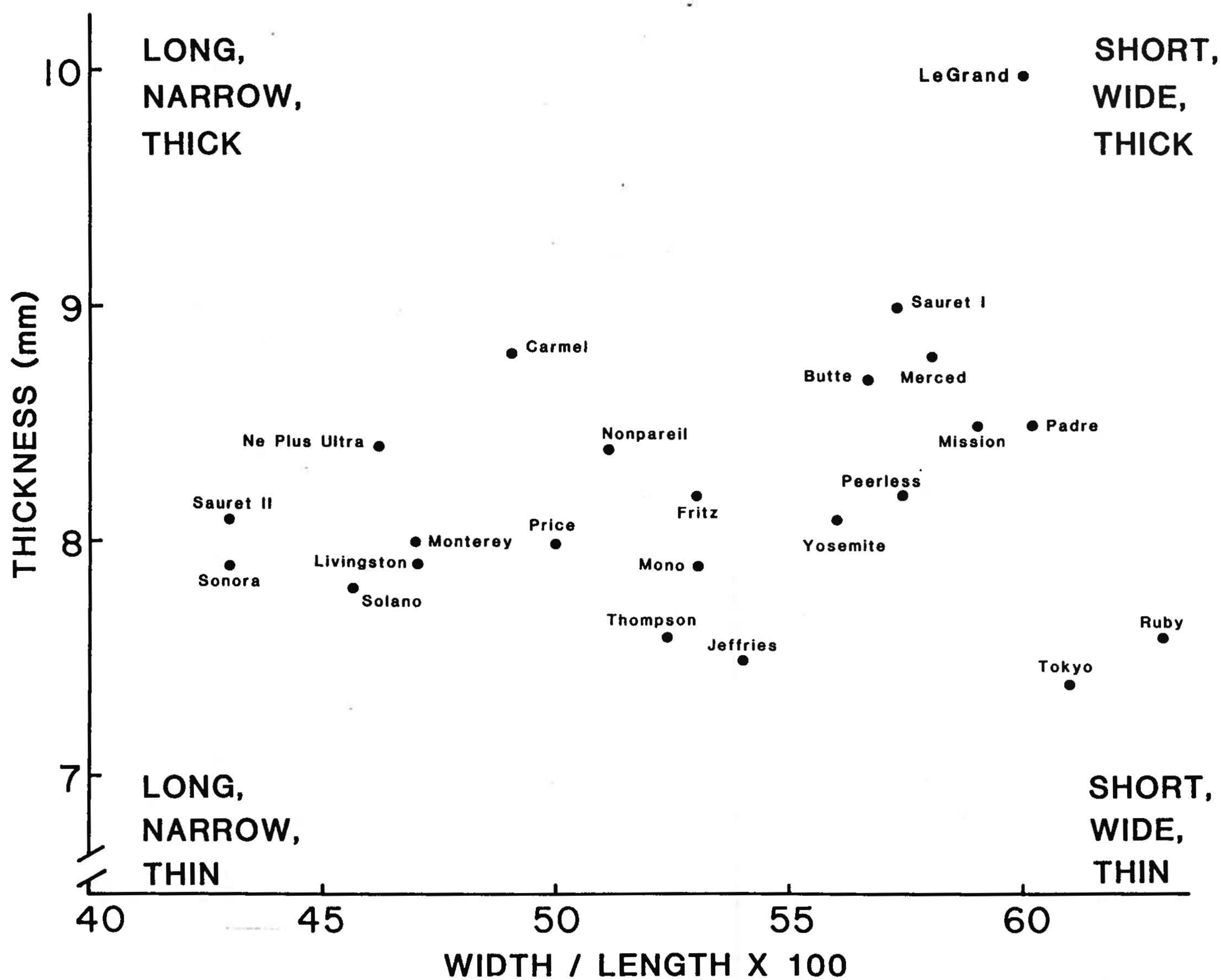

Figure 3. Genotypic variation in kernel shape as indicated by its thickness and width/length ratio.

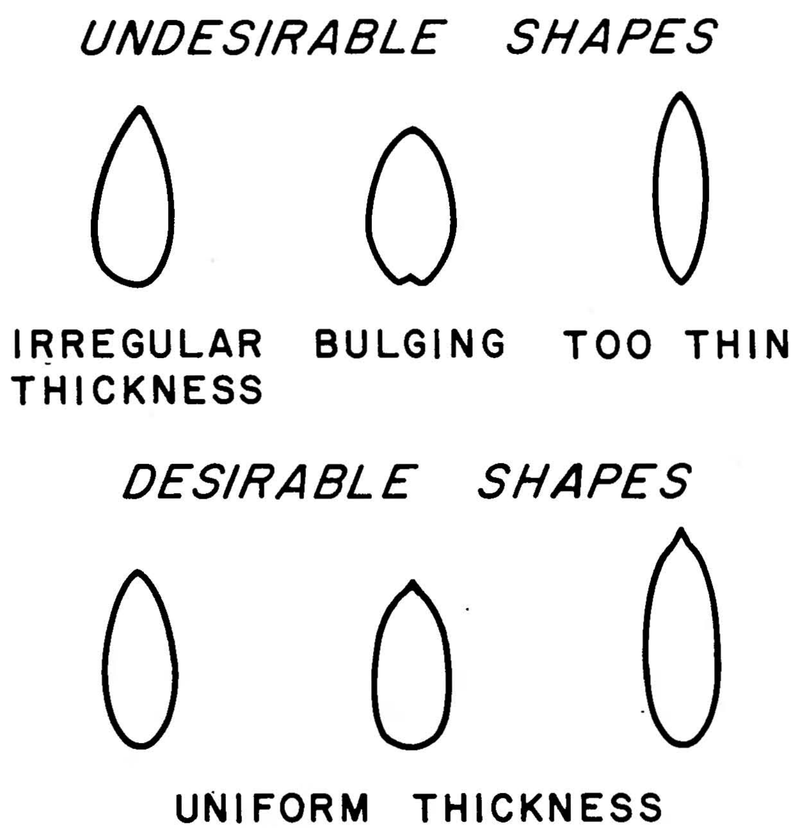

Figure 4. Desirable and undesirable kernel shape as to its yield of intact slices.

Table 6. CLASSIFICATION OF ALMOND VARIETIES ACCORDING TO THEIR KERNEL WEIGHT

Kernel Weight (g)	Varieties
0.9	Butte, Fritz, Padre
1.0	Jeffries, Price, Solano, Yosemite
1.1	Mono, Ruby, Sauret I, Thompson
1.2	LeGrand, Livingston, Merced, Nonpareil, Sauret II, Sonora, Tokyo
1.3	Carmel, Mission, Peerless
1.4	Monterey
1.5	Ne Plus Ultra

Table 7. DEFECTS FOUND IN 23 ALMOND VARIETIES

Variety[z]	No. of Samples	% Defects Doubles	Twins	Twig Borer	Navel OrangeWorm	Blanks	Other	Broken
Butte	1	2	4	0	0	2	0	4
Carmel	1	8	6	2	0	2	0	6
Fritz (K)	2	2	1	0	0	2	0	8
Jeffries (WSFS)	2	3	1	0	0	0	1	1
LeGrand	1	2	0	4	8	6	0	0
Livingston	1	10	0	0	0	2	0	0
Merced	1	6	0	0	0	6	2	4
Mission (K)	16	9	0	0	0	1	1	1
Mono	1	8	0	0	0	0	0	2
Monterey (K)	2	10	0	0	1	2	1	6
Ne Plus Ultra	2	36	0	1	0	4	0	2
Nonpareil	8	1	4.5	1	0	3	0	6
Padre (K)	2	1	0	0	0	0	0	5
Peerless	1	20	0	0	0	0	2	0
Price	1	20	12	0	0	8	4	2
Ruby (K)	2	2	0	0	0	0	0	1
Sauret I	1	9	0	0	0	2	2	6
Sauret II	1	20	4	0	0	10	2	2
Solano	1	0	0	0	0	4	0	6
Sonora	1	0	14	0	0	10	2	10
Thompson (K)	2	2	0	0	0	1	0	2
Tokyo (K)	2	0	1	0	0	0	13	0
Yosemite	1	0	0	1	0	8	0	0

[z]Varieties labeled with a (K) or (WSFS) were harvested from Kern County RVT and West Side Field Station, respectively; all others wre picked from Delta College RVT.

Merced. However, this high degree of damage may have resulted from the use of a sample cracker that was not optimally adjusted.

3. Pellicle Wrinkling. Results of the pellicle wrinkling assessment are given in Table 8. Notably lacking in wrinkling were Nonpareil, Solano and Sonora. Padre was most wrinkled, followed by Ruby, Livingston, Monterey, Mission and Mono. Other varieties were intermediate. Wrinkling may be affected by environmental factors and thus may vary somewhat depending on growing location and season. A smooth appearance is considered most desirable. Wrinkling may be an important factor in salted and flavored nuts because wrinkled nuts may hold more seasoning on their increased surface area. A high degree of wrinkling will also be reflected on the surface of blanched kernels creating an undesirable appearance.

4. Fuzziness. Results of the fuzziness rating are given in Table 9. Padre had the greatest degree of fuzziness followed by Peerless, Ne Plus Ultra, Monterey and Mission. Lowest ratings in this characteristic were for Sonora, Solano, Jeffries and Nonpareil. Further representation of this characteristic is shown in Fig. 5A which are microphotographs of low, medium, and high degrees of fuzziness. Scanning Electron Microphotographs (Fig. 5B) show the kernel surface in greater magnification. The kernel's surface topography influences its salt and flavoring adherence characteristic.

5. Resistance to Mechanical Damage. Results of evaluation of mechanical damage are given in Table 10. The sample cracker used to crack the nuts probably did not achieve results comparable with a production cracker. In general, kernel damage was greater than would be expected. However, significant differences between the varieties was observed. Nonpareil, Solano and Jeffries had virtually no damage while Mission, Monterey, Padre, Peerless and Tokyo had severe damage. The degree of damage was related to kernel yield ($r = 0.69$) and to shell hardness ($r = 0.71$). Nuts with a low percentage of kernel and with hard shells were likely to be damaged more severely.

6. Color. Results of the objective color evaluation are shown in Fig. 6. Nonpareil, Sonora, Solano and Jeffries were the lightest in color while Padre, Ruby,Mission, and Fritz were the darkest. The general color pattern showed that those kernels that were lighter in color had more yellow color as opposed to red whereas the opposite was true for dark kernels.

7. Sensory Characteristics

a. Sweetness: No statistically significant varietal differences in sweetness were observed by the sensory panel (Fig. 7). Sweetness can be an important attribute for the raw kernel market, particularly if a variety can be identified as being unusually sweet. The correlation between sweetness and total sugars content was relatively low ($r = 0.32$)

b. Almond Flavor Intensity: This flavor was defined as that typical of almond extract. Its intensity differed

Table 8. CLASSIFICATION OF ALMOND VARIETIES ACCORDING TO THE DEGREE OF PELLICLE WRINKLING

Descriptive Term	Pellicle Wrinkling Score	Varieties
Smooth	1.0 - 1.9	Nonpareil, Solano, Sonora
Intermediate	2.0 - 2.9	Butte, Carmel, Fritz, Jeffries, LeGrand, Merced, Ne Plus Ultra, Peerless, Price, Sauret II, Thompson, Tokyo, Yosemite
Wrinkled	3.0 - 3.9	Livingston, Mission, Mono, Monterey, Padre, Ruby, Sauret I

Table 9. CLASSIFICATION OF ALMOND VARIETIES ACCORDING TO THE DEGREE OF FUZZINESS OF THEIR KERNELS

Fuzziness Score[z]	Varieties
1.0 - 1.9	Jeffries, Nonpareil, Solano, Sonora
2.0 - 2.9	Butte, Carmel, Fritz, LeGrand, Livingston, Merced, Mono, Price, Ruby, Sauret I, Sauret II, Thompson, Tokyo, Yosemite
3.0 - 3.9	Mission, Monterey, Ne Plus Ultra, Peerless
4.0 - 5.0	Padre

[z] 1 = smooth to 5 = extremely fuzzy

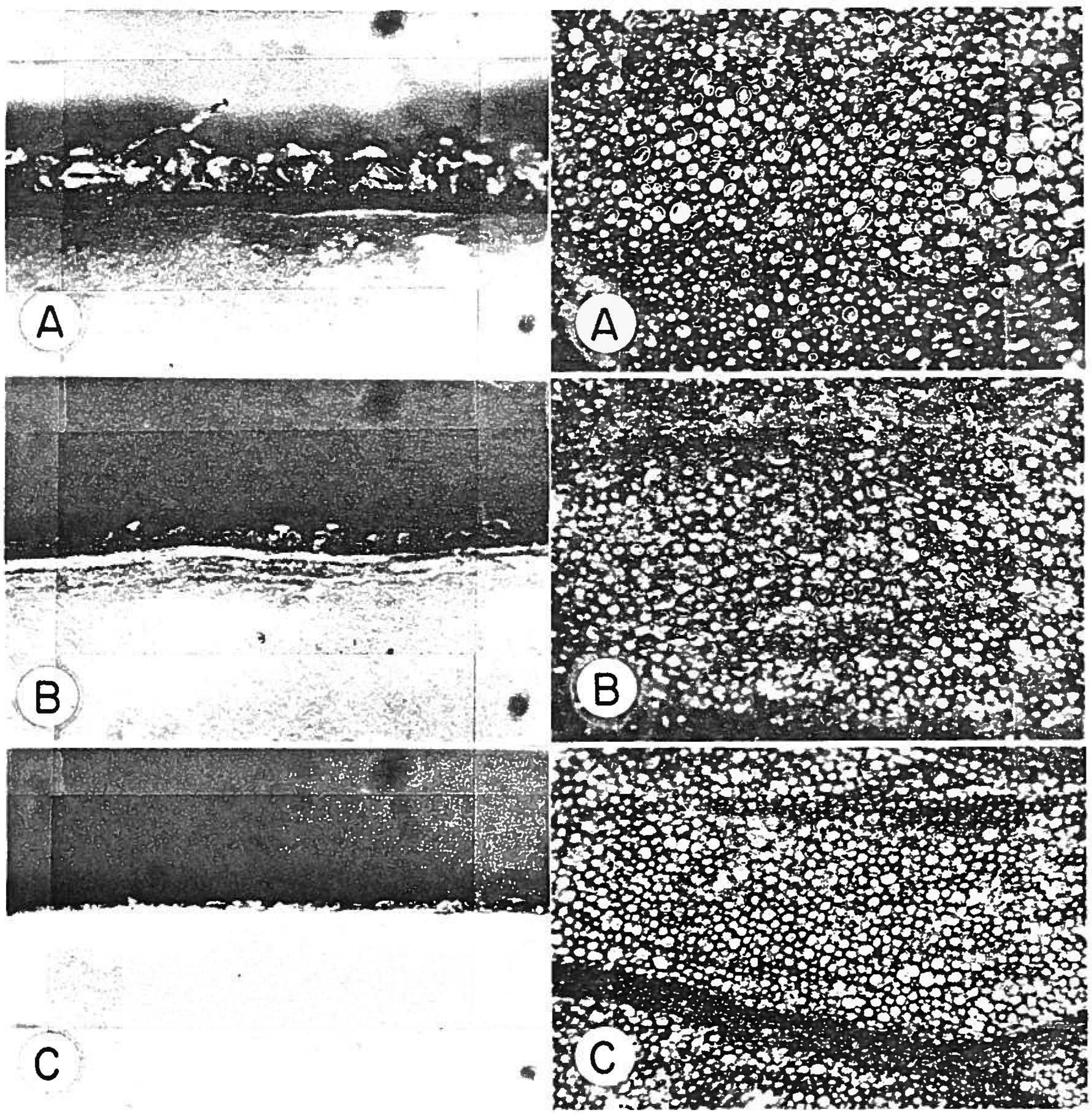

Figure 5A. Variation in kernel surface topography as seen by light microscopy: (A) Padre (most fuzzy), (B) Ruby (intermediate fuzziness), and (C) Sonora (least fuzzy) almonds [left-hand photos = side view, 100x; right-hand photos = top view, 50x].

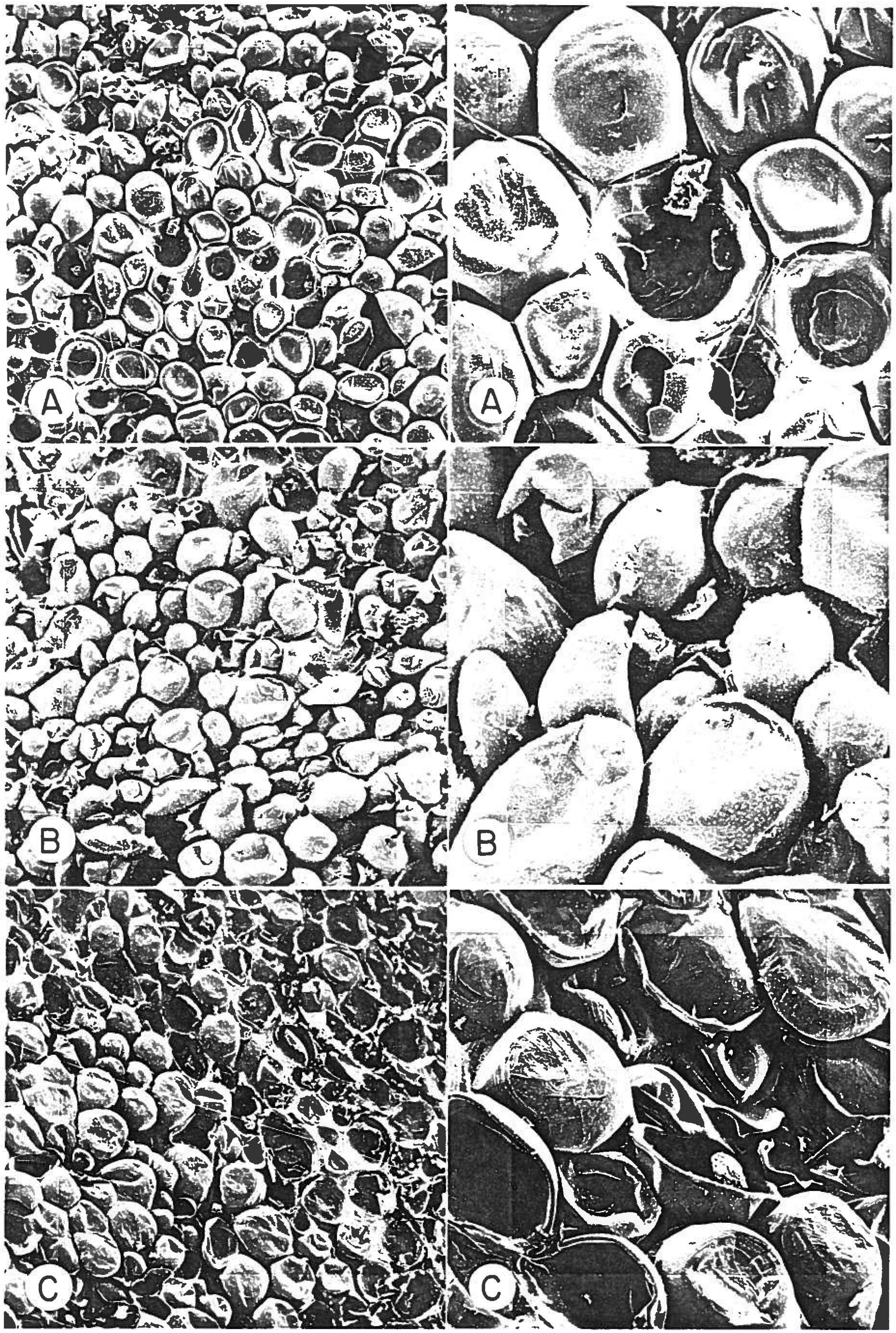

Figure 5B. Variation in kernel surface topography as seen by scanning electron microscopy: (A) Padre (most fuzzy), (B) Ruby (intermediate fuzziness), and (C) Sonora (least fuzzy) almonds [left-hand photos = 78.5x; right-hand photos - 266x].

Table 10. CLASSIFICATION OF ALMOND VARIETIES ACCORDING TO THEIR RESISTANCE TO MECHANICAL DAMAGE DURING CRACKING (AS INDICATED BY THE EXTENT OF DAMAGE TO THE KERNELS)

Resistance to Mechanical Damage Score[z]	Varieties
5.0	Jeffries, Nonpareil, Solano
4.0	Livingston, Sauret I, Sonora
3.5	LeGrand
3.0	Price, Ruby, Thompson
2.5	Merced, Mono, Ne Plus Ultra, Yosemite
2.0	Butte, Sauret II
1.5	Carmel, Fritz
1.0	Mission, Monterey, Padre, Peerless, Tokyo

[z]5 = high resistance (least damage) to 1 = low resistance (greatest damage)

Table 11. CLASSIFICATION OF ALMOND VARIETIES ACCORDING TO OFF-FLAVOR SCORES OF RAW KERNELS

Off-Flavor Score Range[z]	Varieties
0 - 1.5	Jeffries, Mission, Monterey, Nonpareil, Sauret I, Solano, Sonora
1.6 - 2.5	Butte, Carmel, Fritz, Livingston, Merced, Mono, Ne Plus Ultra, Padre, Peerless, Sauret II, Thompson
> 2.6	Price, Ruby, Tokyo, Yosemite

[z]1 = none to 10 = extreme

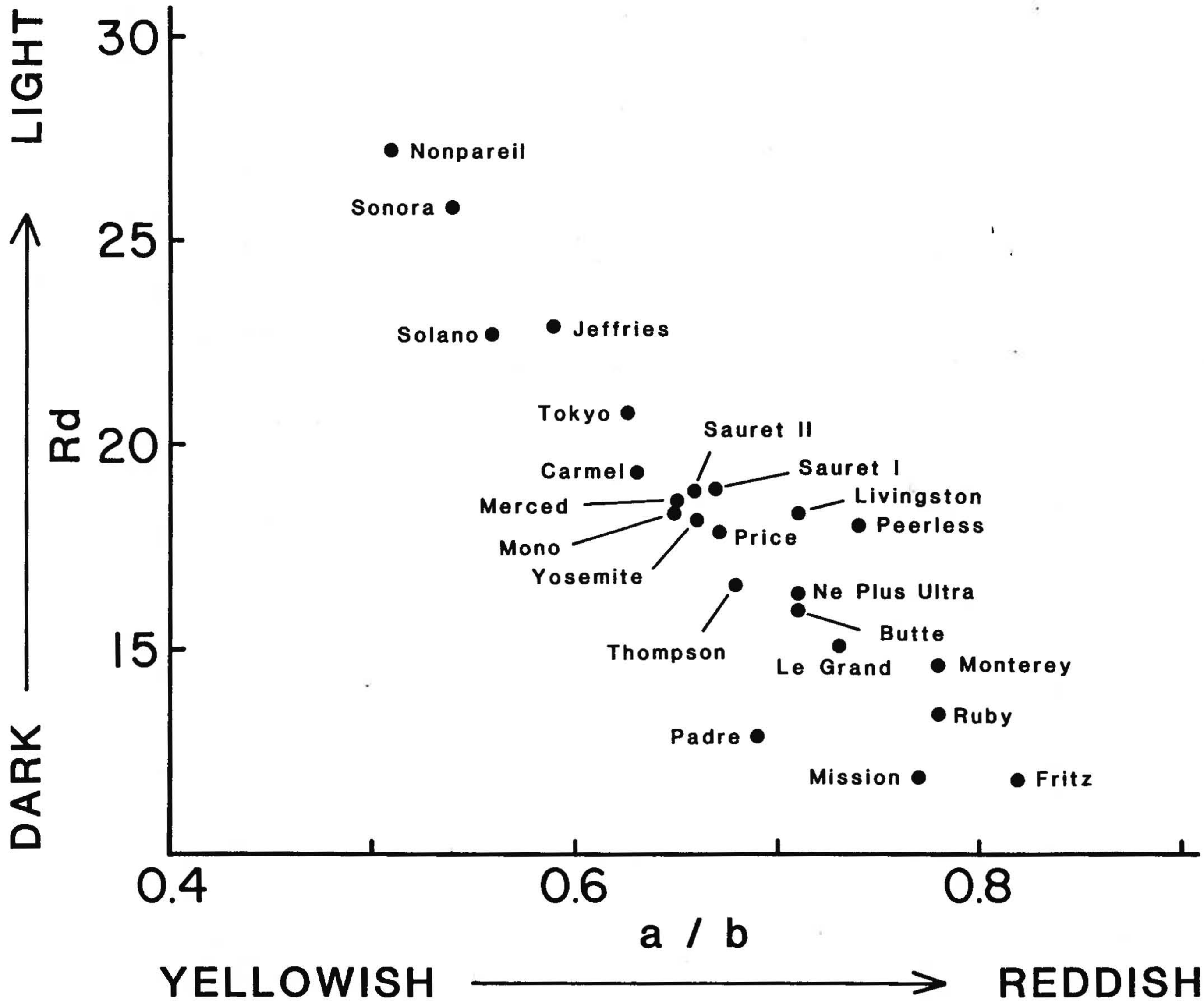

Figure 6. Genotypic variation in kernel color as indicated by Gardner Color Difference Meter's Rd (degree of whiteness or darkness) and a/b ratio (degree of redness/yellowness) values.

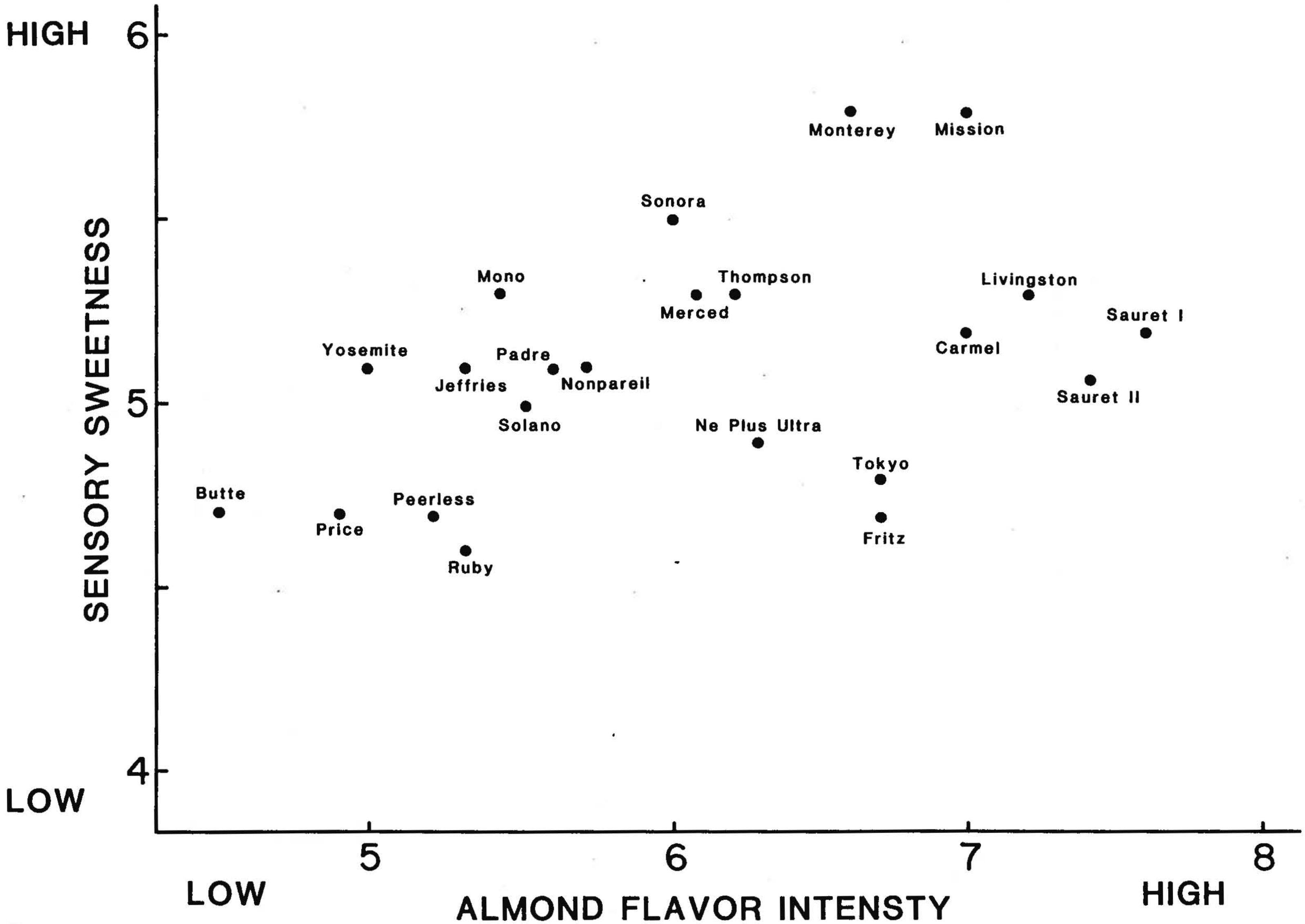

Figure 7. Relationship between sensory evaluation scores for sweetness and almond flavor intensity raw kernels of almond varieties.

significantly among the varieties. Sauret I, Sauret II, Livingston, Carmel and Mission had the most intense almond flavor while Butte, Yosemite and Price had the lowest intensity (Fig. 7). Only a slight relationship was observed between almond flavor intensity and sweetness (r = 0.45), total sugars content (r = -0.11), or total fat content (r = 0.37). For kernels being marketed raw, a high level of almond flavor is desirable, but is not the most important characteristic.

c. Crispness: Sensory crispness scores are shown in Fig. 8. A large grouping of varieties is clustered at the most crisp end of the scale while Livingston, Mono, Price and Sauret II rated least crisp. Crispness was highly negatively correlated (r = 0.79) with moisture content, i.e., nuts with higher moisture content were less crisp. 1984 season nuts were all relatively dry due to hot summer and fall temperatures. Thus, the kernels were all quite crisp. If crispness is of particular importance in the sale of raw kernels, some consideration should be given to moisture adjustment at the processing plant.

d. Firmness: Average firmness scores for all varieties are shown in Fig. 8. With a few exceptions, those nuts that were crisper were also firmer. Mono, Livingston and Price were among the least crisp but were relatively firm. Firmness was also fairly highly and negatively correlated with moisture content (r = 0.70). Although firmness is desirable in a raw kernel, presumably, beyond a certain point, the kernel can be too hard to be eaten comfortably. That point was not determined.

e. Off-Flavor: Off-flavor results are shown in Table 11. Slight off-flavor was most apparent in Price, Ruby, Tokyo and Yosemite. Some subjects were more sensitive to off-flavors than others who detected none. Thus, considerable variation in scoring occurred. The only consistent off-flavor comment was for Price which was occasionally described as musty and stale.

8. Moisture Content. In spite of the equilibration procedure used to equalize kernel moisture, some variation remained. Typically, almonds coming from the field contain 5 to 5.5% kernel moisture. Extremely hot weather in the summer of 1984 resulted in much drier nuts. Even with exposure to 60% relative humidity, all samples, with one exception, remained below 4%. LeGrand was harvested after several rains and had a moisture of 4.5%. The moisture contents of all varieties tested are given in Table 12.

9. Objective Texture - Shear Force. Results of the objective texture testing are summarized in Table 13. These data correlate fairly well with sensory firmness (r = 0.65) but not with sensory crispness (r = 0.19).

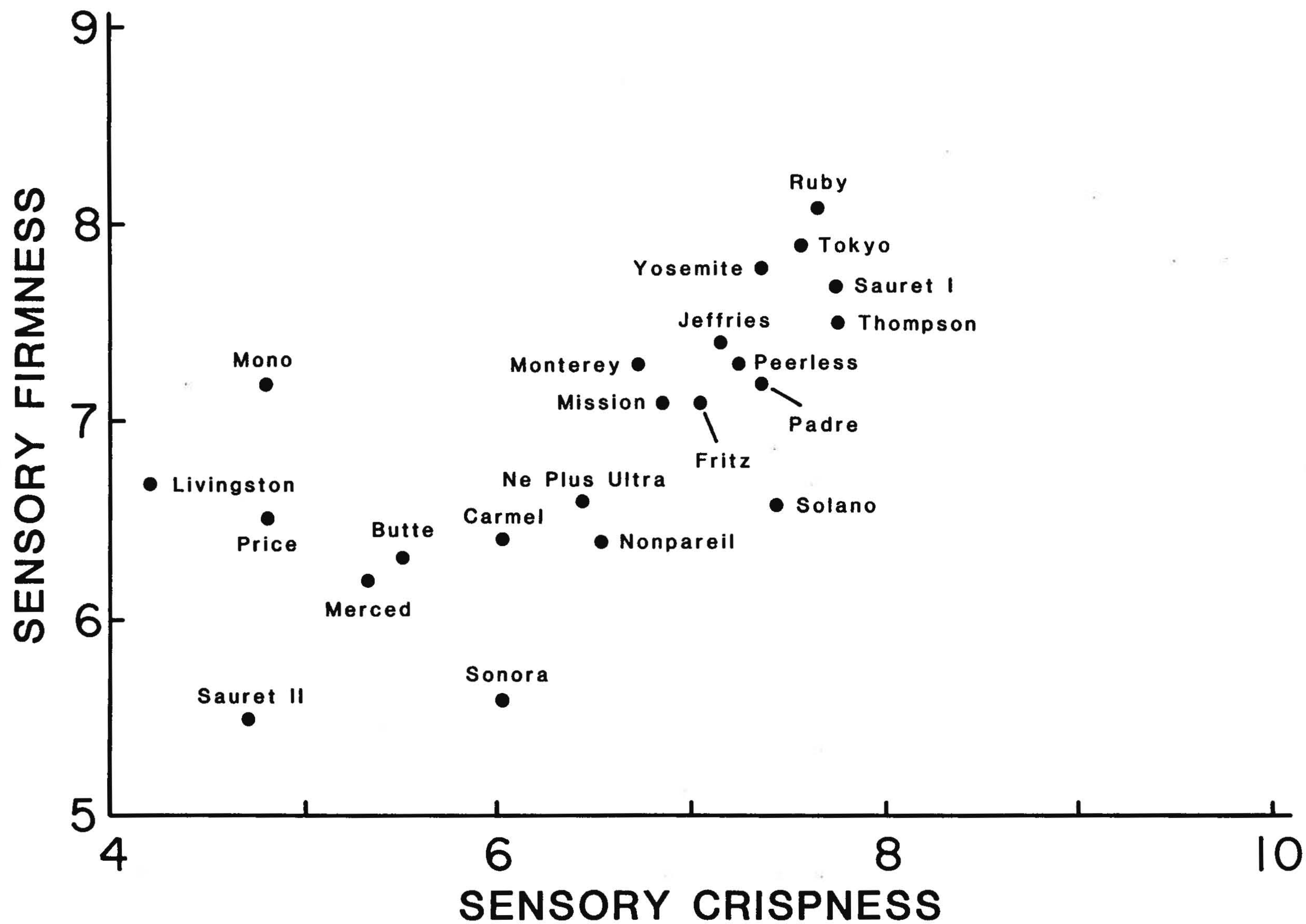

Figure 8. Relationship between sensory evaluation scores for firmness and crispness of raw kernels of 23 almond varieties.

Table 12. CHEMICAL COMPOSITION OF RAW KERNELS OF 23 ALMOND VARIETIES. DATA SHOWN ARE MEANS OF 3 REPLICATES (± SD)

Variety	Moisture Content %	Ether-Extractable Fats %	Total Sugars %
Butte	4.0 ± 0.2	53.4 ± 0.8	5.2 ± 0.2
Carmel	3.7 ± 0.3	56.1 ± 1.1	4.6 ± 0.1
Fritz	3.2 ± 0.2	53.9 ± 0.4	4.8 ± 0.2
Jeffries	3.1 ± 0.2	54.8 ± 0.6	5.8 ± 0.4
LeGrand	4.5 ± 0.1	53.6 ± 0.5	4.7 ± 0.1
Livingston	3.9 ± 0.1	52.9 ± 1.3	5.9 ± 0.4
Merced	3.4 ± 0.3	54.0 ± 0.6	5.5 ± 0.2
Mission	3.4 ± 0.1	53.3 ± 0.9	5.4 ± 0.2
Mono	3.7 ± 0.3	50.9 ± 0.5	5.8 ± 0.5
Monterey	2.9 ± 0.2	56.5 ± 0.4	5.6 ± 0.1
Ne Plus Ultra	3.7 ± 0.1	56.0 ± 0.9	4.1 ± 0.1
Nonpareil	3.0 ± 0.5	55.1 ± 0.8	5.2 ± 0.2
Padre	3.0 ± 0.2	55.1 ± 0.5	6.0 ± 0.5
Peerless	3.1 ± 0.3	54.9 ± 1.1	4.4 ± 0.3
Price	3.5 ± 0.6	49.1 ± 0.7	5.3 ± 0.2
Ruby	3.0 ± 0.2	52.1 ± 0.4	5.2 ± 0.2
Sauret I	2.5 ± 0.4	55.9 ± 0.7	5.5 ± 0.2
Sauret II	3.6 ± 0.3	52.9 ± 0.3	4.6 ± 0.4
Solano	3.1 ± 0.1	54.8 ± 0.6	4.6 ± 0.1
Sonora	3.9 ± 0.2	53.6 ± 0.2	4.8 ± 0.4
Thompson	2.7 ± 0.2	55.3 ± 0.5	5.1 ± 0.1
Tokyo	2.9 ± 0.3	51.7 ± 0.7	5.4 ± 0.2
Yosemite	3.0 ± 0.2	50.0 ± 0.4	5.8 ± 0.1
LSD (5%)	0.4	0.9	0.3

Table 13. CLASSIFICATION OF ALMOND VARIETIES ACCORDING TO FIRMNESS OF RAW KERNELS (AS INDICATED BY THE MAXIMUM FORCE TO SHEAR THE KERNEL USING THE FOOD TECHNOLOGY CORPORATION TEXTURE TEST SYSTEM)

Maximum Shear Force (lbs)	Varieties
25.0 - 30.0	Carmel, LeGrand, Solano
30.1 - 35.0	Butte, Fritz, Ne Plus Ultra, Nonpareil, Padre, Sauret I, Sauret II, Sonora
35.1 - 40.0	Jeffries, Livingston, Merced, Mono, Monterey, Price, Thompson
40.1 - 45.0	Mission, Peerless, Yosemite
45.1 - 50.0	Ruby, Tokyo

Table 14. CLASSIFICATION OF ALMOND VARIETIES ACCORDING TO OFF-FLAVOR SCORES OF ROASTED KERNELS

Off-Flavor Score Range[z]	Varieties
0 - 1.5	Jeffries, Ne Plus Ultra, Peerless, Sonora
1.6 - 2.5	Butte, Carmel, Fritz, Livingston, Merced, Mission, Mono, Monterey, Nonpareil, Padre, Price, Sauret I, Sauret II, Solano, Thompson, Tokyo, Yosemite
> 2.6	Ruby

[z] 1 = none to 10 = extreme

10. Fat Content. The total fat content for the 23 varieties was significantly different and it ranged between 49% in Price and 56.5% in Monterey (Table 12).

11. Total Sugars. As shown in Table 12, total sugars content ranged from 4.1% in Ne Plus Ultra to 6.0% in Padre.

C. Roasted Kernel Evaluation

1. Moisture Content. Moisture content of the roasted kernels was significantly different and ranged from 1.17 to 2.16%. Moisture loss during roasting ranged from 0.81% to 2.70%. The correlation between % raw moisture and % moisture loss during roasting (r = 0.69) indicated that those varieties that had higher moisture contents also lost more moisture during roasting.

2. Sensory Characteristics.

a. Sweetness: Fig. 9 shows the average sweetness scores for all varieties. Slight but significant differences are seen which are somewhat related to sweetness in raw kernels (r = 0.32). There was a good correlation between sweetness (roasted) and total sugar content of the kernels.

b. Almond Flavor Intensity: Average scores for almond flavor intensity are also given in Fig. 9. Significant differences were observed, but when compared with the data from the raw kernels, it is seen that the scores are much lower and there is much less difference between the varieties. This finding indicates that the characteristic "almond flavor" is either lost or masked by the roasting process. The almonds become very much alike in terms of flavor as a result of roasting. Almost no relationship (r = 0.06) was found between raw and roasted kernels for this characeristic.

c. Crispness: Sensory crispness scores are shown in Fig. 10. Even more dramatic than the change in flavor due to roasting is the change in crispness. As would be expected, as a result of the roasting process, the kernels dry out and become crisper. The surprising finding is that, after roasting, crispness of all the varieties is very nearly the same. Crispness in roasted kernels bore almost no relationship (r = -0.04) to crispness in raw kernels).

d. Firmness: Firmness scores are also shown in Fig. 10. Overall, the roasted kernels were slightly less firm than the raw kernels. Some significant differences were found between varieties with Livingston, Price and Mono being firmest and Solano, Fritz and Thompson least firm. Very little relationship (r = -0.12) was observed between raw and roasted kernels.

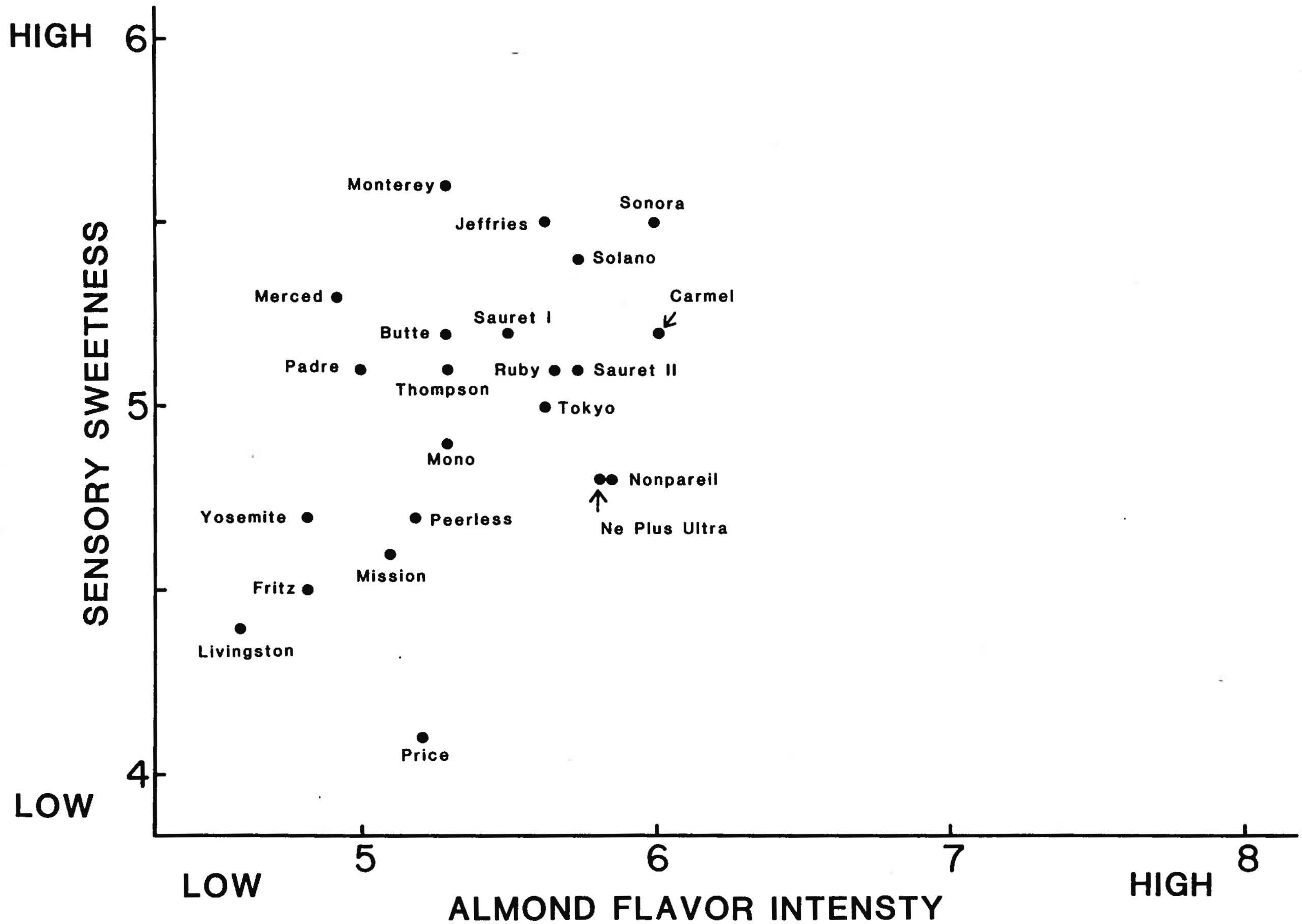

Figure 9. Relationship between sensory evaluation scores for sweetness and almond flavor intensity of roasted kernels of almond varieties.

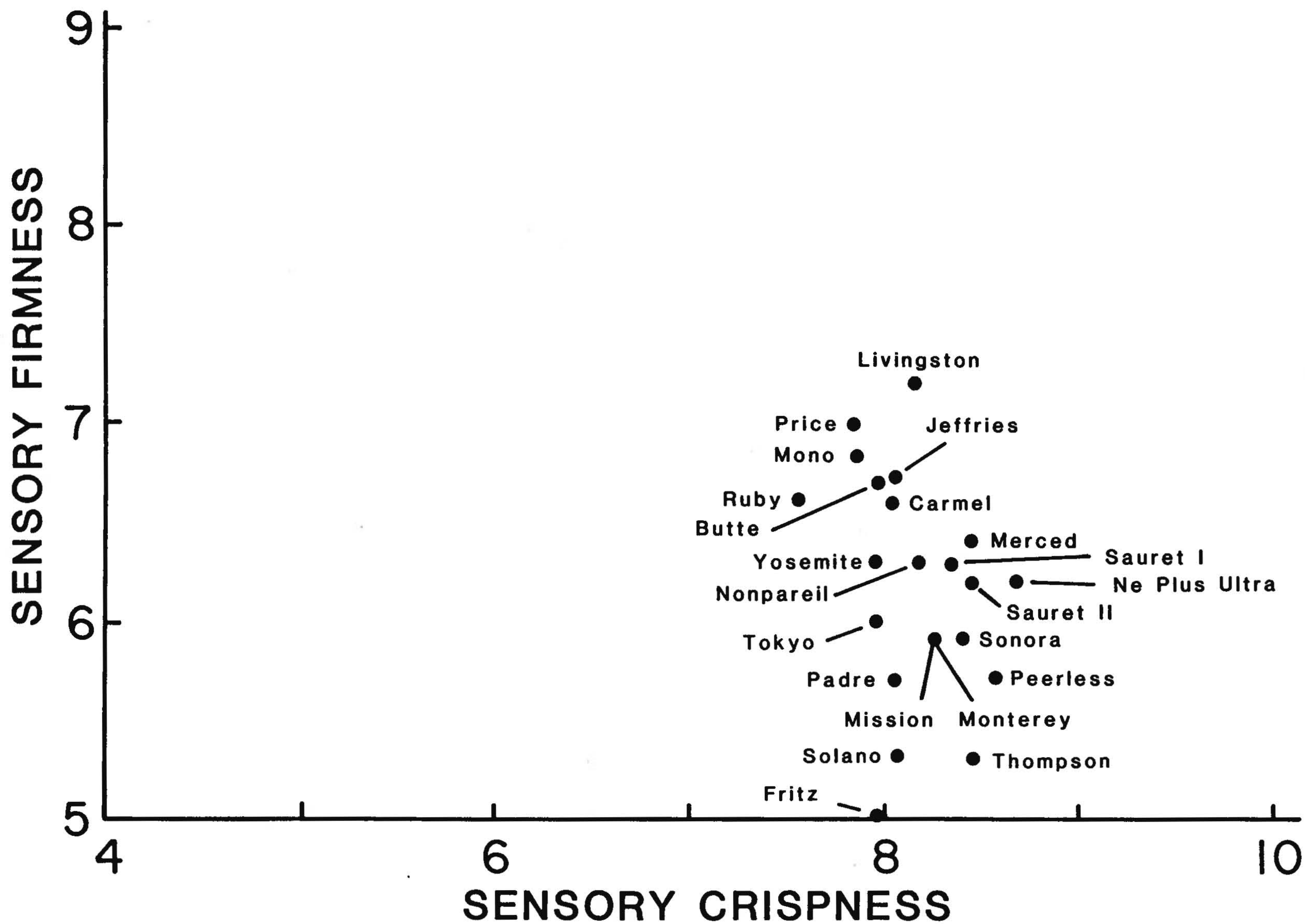

Figure 10. Relationship between sensory evaluation scores for firmness and crispness of roasted kernels of almond varieties.

e. Off-Flavor: Off-flavor scores are summarized in Table 14. Ruby had the highest degree of off-flavor and it was among the highest in the raw evaluation also. However, in general, there was not very good correspondence between off-flavors in raw and roasted kernels (r = 0.41). Among the most frequent comments made by the panelists was "burned," suggesting overroasting. Since this would not occur in raw kernels, it is not surprising to see a different pattern in the roasted kernels. Occasional "rancidity" comments were also made.

E. Blanched Kernel Evaluation

1. Skinning Difficulty (Stickers), Swelling, Skin Thickness. Results of these evaluations are summarized in Table 15 and Fig. 11. Based on these data and the percentage of splits (see raw natural evaluation), Butte, Carmel, Jeffries, Nonpareil, and Sonora appear to be the best candidates for blanching.

2. Color-Objective Evaluation. Fig. 12 shows the results of the colorimeter evaluation of whole blanched kernels. The most meaningful measurements were Rd (lightness) and YI (yellowness index). The lightest kernels (high Rd) are the most desirable. The darkest kernels tend to be yellowish (high YI) or grayish (low YI), both undesirable. Peerless was the most uniform in Rd, while Ne Plus Ultra was the most uniform in YI. Sonora was least uniform in Rd and Fritz and Merced were least uniform in YI. LeGrand, Merced, Mono, and Yosemite, were probably outside the desirable color limits.

Table 15. CLASSIFICATION OF ALMOND VARIETIES ACCORDING TO THEIR BLANCHING CHARACTERISTICS AS INDICATED BY SKINNING DIFFICULTY, SKIN SWELLING, AND SKIN THICKNESS

Characteristic	Score	Varieties	Score	Varieties
Skinning difficulty[z]	1	Livingston, Merced, Mono, Tokyo	6	Monterey
	2	Butte, Carmel, Jeffries, Nonpareil	7	Padre, Sauret II
	3	Ruby, Sauret I, Sonora, Thompson	8	Fritz
	4	Peerless, Yosemite	9	
	5	LeGrand, Ne Plus Ultra, Price, Solano	10	Mission
Skin swelling[y]	1	Butte, Livingston, Merced, Mono, Nonpareil, Price, Tokyo	6	Ne Plus Ultra, Solano
	2	Ruby, Sauret I	7	Padre
	3	Jeffries, Sonora, Thompson	8	Sauret II
	4	LeGrand, Yosemite	9	Fritz, Monterey
	5	Peerless	10	Carmel, Mission
Skin thickness[x]	1	Nonpareil, Solano, Sonora, Tokyo	6	Padre, Peerless
	2	Carmel, Mono, Price	7	Monterey
	3	Butte, Jeffries, Livingston, Merced, Sauret I, Thompson	8	Fritz, Mission, Ruby
	4		9	Ne Plus Ultra
	5	LeGrand, Sauret II, Yosemite	10	

[z]1 = easy to remove skin to 10 = very difficult to remove skin
[y]1 = much swelling to 10 = little swelling
[x]1 = thin to 10 = thick

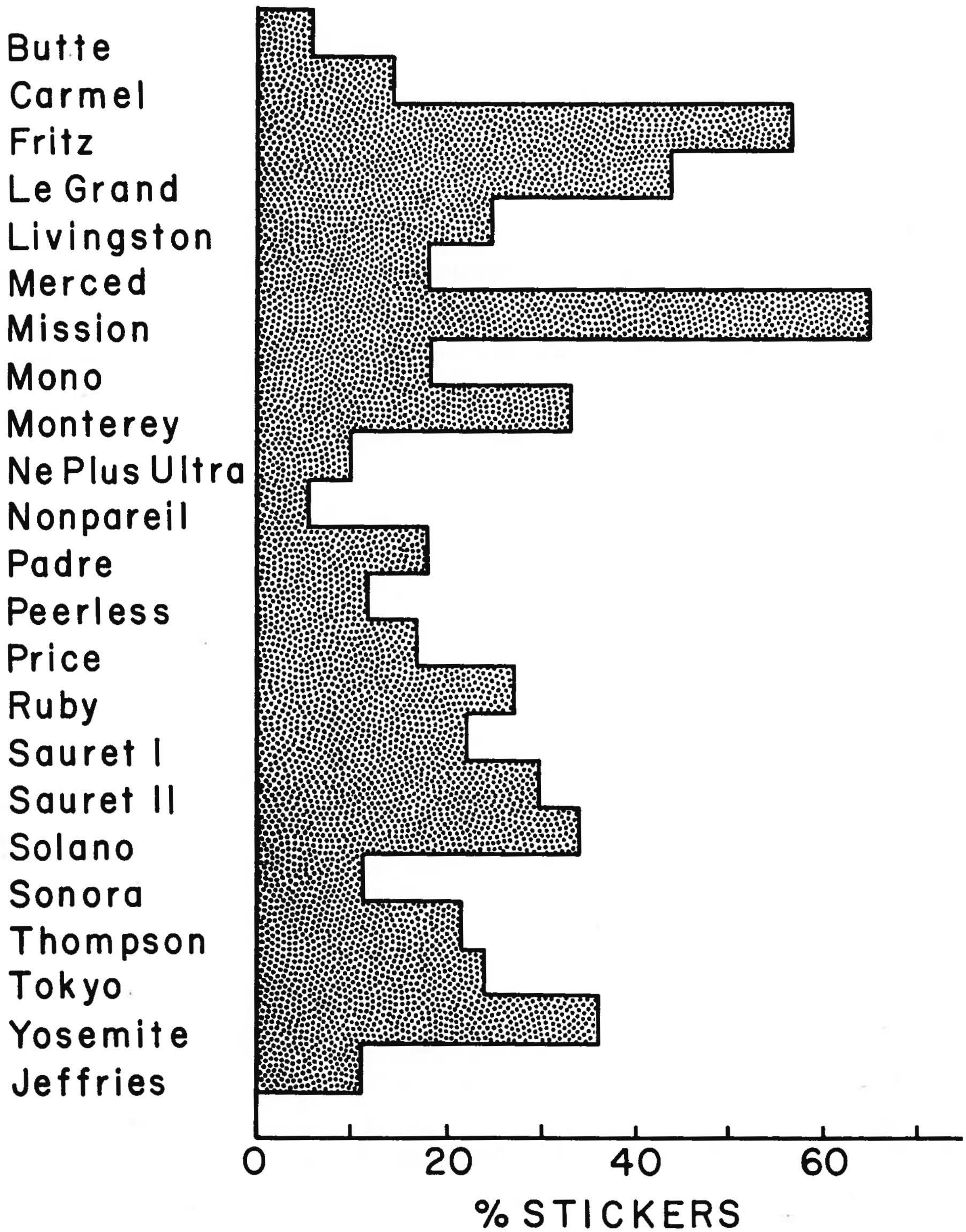

Figure 11. Genotypic variation in ease of kernel blanching as indicated by the percent of kernels with skin fragments remaining after blanching.

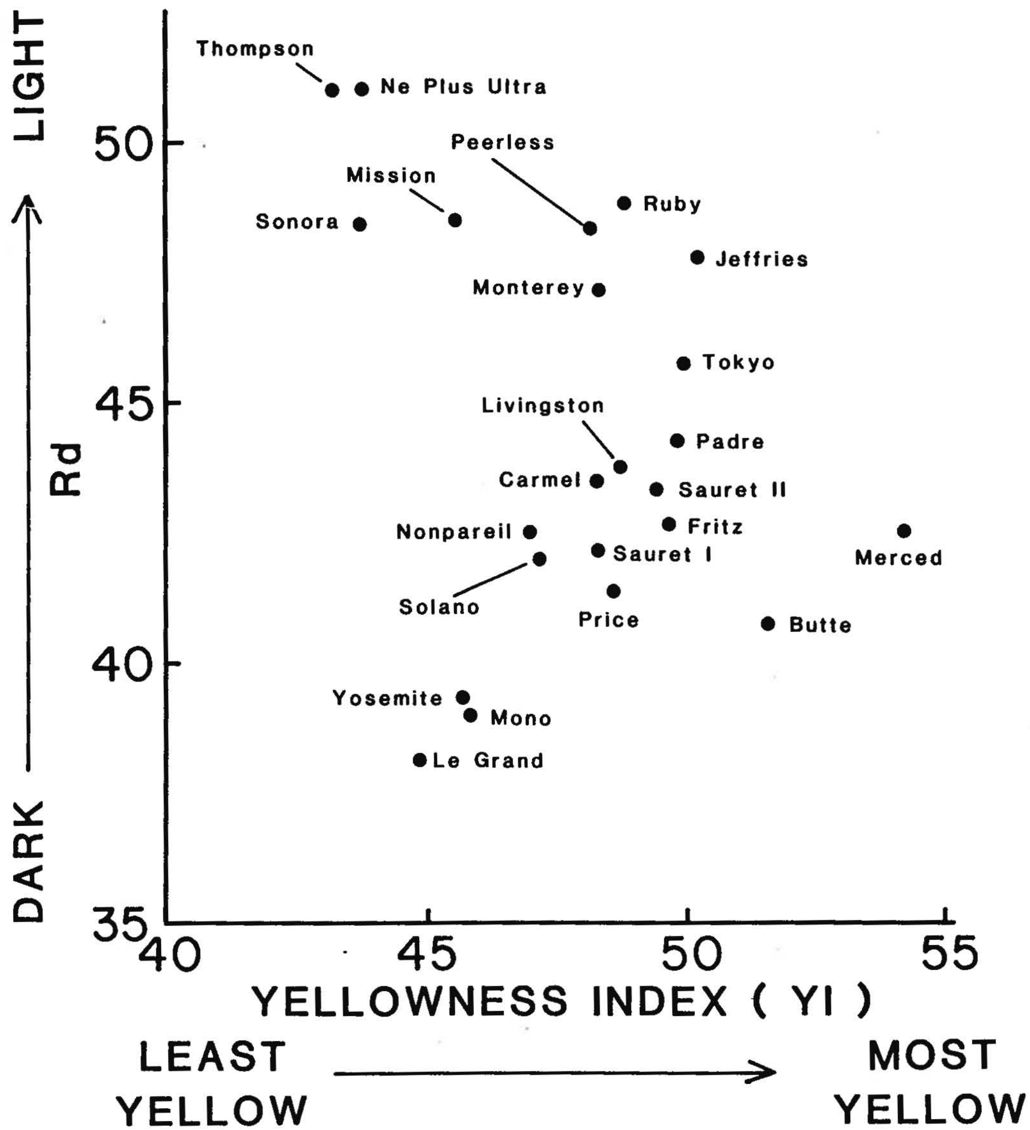

Figure 12. Genotypic variation in blanched kernel color as indicated by Gardner Color Difference Meter's Rd (degree of whiteness or darkness) and YI (yellowness index) values.

CONCLUSIONS:

A. Important characteristics for each marketing outlet

1. In-shell Nuts:

a. Large, hard-shelled varieties are desirable for in-shell marketing. However, it may be possible to market semi-hard-shelled varieties if shipping containers, such as fiberboard boxes, are used to provide more protection to the nuts than those currently used (mostly jute sacs).

b. The shell must have little or no abrasion due to hulling and must be light in color or bleachable.

c. The shell suture must be tight to protect the kernel from contamination and insect infestation. Shell porosity may also be a factor in suitability for bleaching.

d. The kernel should be free from defects and off-flavors and should have a firm and crisp texture and a good almond flavor.

e. High kernel yield (percent edible portion) is preferred.

2. Raw Natural Kernels:

a. Shell hardness is also important for varieties marketed as raw natural kernels. Varieties with hard shells are more difficult to crack and tend to incur more kernel damage than those with softer shells.

b. Varieties whose shell suture is closed are preferred to provide for better sanitation and greater protection to the kernel against insects during handling and storage before cracking. A high kernel yield is preferred, but high percent kernel is usually associated with poorly-sealed shells.

c. Specific size and shape requirements vary with intended use of the kernels, but they should be relatively uniform.

d. Kernels must be resistant to mechanical damage (chipping, breakage) and should have minimal amount of defects such as twins, doubles, and splits.

e. Skin (pellicle) color of the kernels should be light-brown and not excessively thick, wrinkled, or fuzzy.

f. Kernels should be free from off-flavors and should have a firm, crisp texture.

3. Roasted Kernels:

a. All the characteristics mentioned above for raw natural kernels are also important for roasted kernels.

b. Since almond flavor intensity, which is high in raw kernels, is reduced upon roasting and differences among varieties are largely obscured, certain varieties with low almond flavor intensity may be more marketable as roasted kernels than as raw kernels.

Table 16. Suitability[z] of almond varieties for various marketing outlets on the basis of the 1984 evaluations.

	Marketing outlet					
Variety	In-Shell	Raw or roasted natural	Roasted & salted or flavored	Blanched	Sliced	Slivered
Butte	2	2	2	1	3	2
Carmel	3	3	2	1	1	2
Fritz	2	3	2	3	2	2
Jeffries	3	1	2	1	3	3
LeGrand	3	1	2	2	3	2
Livingston	3	1	2	1	3	1
Merced	3	2	2	1	3	2
Mission	1	3	1	3	3	2
Mono	2	2	2	1	2	2
Monterey	3	3	1	3	2	1
Ne Plus Ultra	3	2	2	3	2	1
Nonpareil	3	1	2	1	1	2
Padre	1	3	1	2	3	2
Peerless	1	3	2	2	3	2
Price	3	2	2	2	2	2
Ruby	2	1	2	2	2	3
Sauret I	3	1	2	1	1	2
Sauret II	3	2	2	3	2	1
Solano	3	1	2	2	2	1
Sonora	3	1	2	1	2	1
Thompson	2	1	2	1	3	3
Tokyo	3	3	2	1	3	3
Yosemite	3	2	2	2	3	2

[z]Degree of suitability: 1 = high, 2 = moderate, 3 = low

4. Salted or Flavored Roasted Kernels:

   a. All the characteristics stated above for raw and roasted kernels are also important for varieties marketed as roasted and salted or flavored kernels.
   b. One additional criterion is the ability of salt and/or flavoring powders to adhere to the kernel's surface, which may be related to the degree of skin wrinkling and fuzziness. Too much salt adhering to the kernel can also be a problem in excessively wrinkled and/or fuzzy varieties.

5. Blanched Kernels:

   a. All the characteristics listed above for raw natural kernels are applicable to blanched kernels.
   b. In addition, the kernels must be easily blanched and the whiteness of the blanched kernels is desirable.

6. Sliced or Slivered Kernels:

   a. In addition to the characteristics mentioned above for raw natural kernels, shape is very important since it influences yield of slices or slivers.
   b. Kernels that are large, relatively thick, and uniform in thickness are most desirable.

B. Suitability of Selected Almond Varieties for Various Marketing Outlets

On the basis of the stated-above important characteristics for each marketing outlet and the quality evaluations made during the 1984 season on 23 almond varieties, their suitability for various marketing outlets is summarized in Table 16.

While varieties marketed in-shell cannot be mixed (because of their differences in shell size, shape, and color), those marketed in other forms might be mixed within certain groups depending on similarity of kernel size, shape, and color. The 23 varieties used in this study can be classified according to similarity in kernel size, shape, and color (for marketing as raw natural kernels) as follows:

Group (kernel characteristics)	Varieties
1. Large, light-colored	Solano, Sonora
2. Large, medium-colored	Livingston, Sauret II
3. Large, dark-colored	Monterey, Ne Plus Ultra
4. Medium, light-colored	Jeffries, Monpareil
5. Medium, medium-colored	Carmel, Mono, Price
6. Medium, dark-colored	Fritz, Thompson
7. Small, medium-colored	Merced, Peerless, Sauret I, Tokyo, Yosemite
8. Small, dark-colored	Butte, LeGrand, Mission, Padre, Ruby

For marketing as roasted (natural or flavored) kernels, varieties in groups 2 and 3 or 5 and 6 or 7 and 8 can be mixed since roasting time can be adjusted to attain a similar roasted color. Varieties in groups 1, 2 and 3 or 4, 5 and 6 or 7 and 8 can be mixed if marketed after blanching.

C. Proposed Procedures for Future Quality Evaluation of Almond Genotypes

The following procedures are suggested for use in evaluating all advanced breeding lines which have passed the test for yield and related preharvest factors. This quality evaluation procedure can also be used to determine the suitability of recently introduced varieties for various marketing outlets. All the evaluations mentioned below should be done on 3 replicates of 100 nuts each.

1. All advanced breeding lines should be tested for off-flavors such as bitter taste and those with any off-flavors should be discarded.

2. Check shell integrity after hulling and extent of suture opening. Genotypes with excessive suture opening should be discarded.

3. Check shell hardness (penetration force) and color (visual scoring). Varieties with hard shell can be marketed in-shell if shell color is light or bleachable to obtain a light color.

4. Crack the samples, then evaluate the kernels for extent of mechanical damage due to cracking and for naturally-occurring defects such as twins, doubles, splits, and insect damage. Eliminate any genotype which consistently exhibit high level of defects.

5. For the remaining genotypes, determine kernel color (either by light reflectance or visual scoring), weight, length, width, and thickness and degree of uniformity for each of these parameters. Calculate percent edible portion (kernel weight relative to in-shell weight) and determine to which group does each genotype belong from the kernel color, size and shape standpoint.

6. On the basis of kernel size and shape, determine the suitability of each genotype for marketing as raw or roasted natural kernels, sliced, or slivered.

7. Determine the degree of kernel wrinkling and fuzziness. Genotypes with more wrinkled and fuzzy surface are more suitable for marketing as roasted and salted or flavored.

8. Test all genotypes which are marketable as raw natural kernel for the ease of blanching (as indicated by percent kernels with skin remnants) and degree of whiteness of the blanched kernels to identify those genotypes that are suitable for marketing as blanched kernels.

APPENDIX

Table A-1. In-shell physical characteristics of almond varieties. Data shown are means of 30 measurements except in the last column where an overall score was assigned to each variety.

Variety[z]	Shell integrity: Intactness score[y]	Shell integrity: Suture opening[x]	Shell hardness lbf	Shell color reflectance values: Rd	Shell color reflectance values: a	Shell color reflectance values: b	In-shell weight g	Kernel weight g	Kernel %	Kernel resistance to mech. injury[v]
Butte	4.8	1.8	10.9	31.6	6.4	17.8	1.5	1.0	67	2.0
Carmel	4.2	1.5	8.9	22.4	9.7	18.5	1.9	1.3	68	1.5
Fritz (K)	4.3	1.8	13.2	26.4	9.0	20.9	1.7	1.0	57	1.5
Jeffries (WSFS)	2.1	1.2	8.2	32.3	7.2	20.0	1.4	1.0	71	5.0
LeGrand	2.4	1.3	9.4	26.8	7.8	20.3	1.7	1.2	71	3.5
Livingston	3.6	1.2	7.7	30.7	7.0	18.9	1.8	1.2	67	4.0
Merced	3.7	1.4	7.7	29.3	7.0	18.0	1.7	1.2	75	2.5
Mission (K)	4.1	2.0	20.3	24.9	8.3	18.8	2.5	1.2	49	1.0
Mono	3.6	1.8	14.5	31.8	7.4	19.2	2.0	1.1	52	2.5
Monterey (K)	1.5	1.8	16.0	19.3	10.9	19.3	2.2	1.3	59	1.0
Ne Plus Ultra	3.1	1.3	10.7	34.0	6.0	19.8	2.7	1.8	67	2.5
Nonpareil	4.5	1.7	7.0	23.2	9.1	19.1	1.7	1.2	76	5.0
Padre (K)	4.0	2.0	13.3	23.9	7.7	18.1	1.7	0.9	53	1.0
Peerless	4.1	2.0	24.3	35.6	6.7	20.0	3.2	1.4	44	1.0
Price	4.0	1.4	7.5	21.7	9.9	17.9	1.6	1.0	75	3.0
Ruby (K)	3.9	1.8	13.9	34.8	7.0	20.3	2.0	1.1	55	3.0
Sauret I	3.1	1.3	7.1	22.1	8.0	16.4	1.5	1.1	80	4.0
Sauret II	3.9	1.6	10.5	26.6	9.4	19.8	2.1	1.4	67	2.0
Solano	4.5	1.6	7.7	33.7	6.2	18.4	1.5	1.0	67	5.0
Sonora	3.3	1.2	8.6	29.1	7.6	17.9	1.7	1.3	76	4.0
Thompson (K)	4.5	1.9	7.1	26.3	9.3	19.1	1.7	1.0	65	3.0
Tokyo (K)	3.6	1.4	24.2	27.8	9.3	21.3	2.7	1.3	48	1.0
Yosemite	3.0	1.7	14.0	38.2	5.1	18.1	1.8	1.0	56	2.5
LSD (5%)	0.5	0.2	2.0	2.3	0.7	0.9	0.2	0.1	--	---

[z]Varieties labeled with a (K) or (WSFS) were harvested from Kern County RVT and West Side Field Station, respectively; all others were picked from Delta College RVT.
[y]1 = 0-10% intact to 5 = 96-100% intact shell.
[x]1 = open, 2 - sealed
[v]1 = least resistant to 5 = most resistant

Table A-2. Raw natural kernel's physical characteristics of almond varieties. Data shown are means of 30 measurements.

Variety[z]	Fuzziness score[y]	Skin wrinkling score[x]	Weight g	Width mm	Length mm	Thickness mm	Relative shear force	Color reflectance values Rd	a	b
Butte	2.1	2.9	0.9	10.9	19.2	8.7	33.3	16.0	13.3	18.7
Carmel	2.3	2.5	1.3	11.7	23.8	8.8	30.1	19.3	12.7	20.2
Fritz (K)	2.1	2.8	0.9	10.9	20.6	8.2	30.3	11.9	11.9	14.5
Jeffries (WSFS)	1.5	2.2	1.0	11.6	21.5	7.5	37.1	22.9	13.2	22.2
LeGrand	2.0	2.9	1.2	12.3	20.6	9.9	30.0	15.1	13.0	17.7
Livingston	2.0	3.1	1.2	11.6	24.7	7.9	36.1	18.3	13.7	19.4
Merced	2.2	2.8	1.2	12.4	21.4	8.8	36.7	18.7	12.8	19.7
Mission (K)	3.1	3.1	1.3	13.2	22.7	8.5	41.7	11.9	11.4	14.8
Mono	2.0	3.0	1.1	11.7	22.0	7.9	38.5	18.4	13.0	19.9
Monterey (K)	3.2	3.1	1.4	12.6	26.7	8.0	38.6	14.7	13.2	16.9
Ne Plus Ultra	3.6	2.9	1.5	12.6	27.3	8.4	34.0	16.4	13.0	18.4
Nonpareil	1.5	1.7	1.2	11.8	23.1	8.4	34.3	27.2	11.7	22.9
Padre (K)	4.9	3.9	0.9	11.0	18.3	8.5	31.1	12.9	9.8	14.2
Peerless	3.9	2.8	1.3	13.0	23.1	8.2	40.9	18.0	13.9	18.7
Price	2.0	2.9	1.0	10.8	21.5	8.0	39.5	17.9	13.2	19.6
Ruby (K)	2.9	3.2	1.1	13.3	21.1	7.6	49.5	13.4	13.0	16.7
Sauret I	2.0	3.0	1.1	11.9	20.8	9.0	33.0	19.1	13.4	19.9
Sauret II	2.1	2.8	1.2	11.1	26.1	8.1	31.6	18.9	12.8	19.9
Solano	1.5	1.6	1.0	10.3	22.6	7.8	25.9	22.8	12.1	21.8
Sonora	1.1	1.8	1.2	11.1	25.9	7.9	30.4	25.9	12.5	23.3
Thompson (K)	2.9	2.9	1.1	12.3	23.5	7.6	37.5	16.7	12.4	18.3
Tokyo (K)	2.6	2.3	1.2	14.2	23.4	7.4	47.6	20.9	12.2	19.5
Yosemite	2.4	2.6	1.0	11.4	20.4	8.1	42.9	18.3	13.0	19.7
LSD (5%)	0.2	0.2	0.1	0.3	0.7	0.3	4.2	1.1	0.5	0.6

[z]Varieties labeled with a (K) or (WSFS) were harvested from Kern County RVT and West Side Field Station, respectively; all others were picked from Delta College RVT.
[y]1 = smooth to 5 = extremely fuzzy
[x]1 = no wrinkling to 5 = extreme wrinkling

Table A-3. Raw natural kernel's physical characteristics related to shape and slicing yield of almond varieties.

Variety[z]	Thickness (A) 3mm from bottom (mm)	Thickness (B) 4mm from top (mm)	(C) A-B	(D) Maximum thickness (mm)	D-A	Length (mm)
Butte	8.2	5.2	3.0	8.2	0	19.3
Carmel	7.8	6.4	1.4	8.6	0.8	24.1
Fritz (K)	7.4	5.1	2.3	8.2	0.8	21.0
Jeffries (WSFS)	6.8	6.0	0.8	7.5	0.7	21.7
LeGrand	7.9	6.0	1.9	9.7	1.8	20.4
Livingston	6.7	5.7	1.0	7.6	0.9	25.0
Merced	7.7	5.5	2.2	8.2	0.5	22.3
Mission (K)	7.6	4.9	2.7	8.2	0.6	21.1
Mono	6.7	6.4	0.3	7.5	0.8	23.0
Monterey (K)	6.8	5.3	1.5	7.5	0.7	25.2
Ne Plus Ultra	7.6	4.9	2.7	7.9	0.3	28.1
Nonpareil	7.5	7.2	0.3	8.3	0.8	23.3
Padre (K)	7.8	5.2	2.6	7.9	0.1	17.7
Peerless	7.4	4.4	3.0	7.8	0.4	23.0
Price	7.2	6.0	1.2	7.8	0.6	21.8
Ruby (K)	6.9	6.6	0.3	7.6	0.7	21.4
Sauret I	7.9	7.3	0.6	8.5	0.6	21.6
Sauret II	6.8	5.7	1.1	7.7	0.9	26.8
Solano	7.1	6.4	0.7	7.9	0.8	23.2
Sonora	7.0	6.1	0.9	7.8	0.8	26.7
Thompson (K)	6.6	6.1	0.5	7.2	0.6	23.9
Tokyo (K)	------------------- no data collected -----------------					
Yosemite	7.4	6.8	0.6	8.1	0.7	20.4

[z]Varieties labeled with a (K) or (WSFS) were harvested from Kern County RVT and West Side Field Station, respectivly; all others were picked from Delta College RVT.

Table A-4. Genotypic variation in blanching characteristics and color of blanched kernels of almond varieties. Color data shown are means of 30 measurements.

Variety[z]	Stickers (%)	Skinning difficulty score[y]	Skin thickness score[x]	Degree of swelling score[v]	Color reflectance values				
					Rd	a	b	YI	WI
Butte	5.9	2	3	1	40.8	2.1	18.2	51.6	-23.4
Carmel	14.0	2	2	10	43.6	1.7	17.7	48.2	-21.3
Fritz (K)	56.9	8	8	9	42.6	0.7	18.4	49.7	-23.7
Jeffries (WSFS)	10.8	2	3	3	47.8	1.1	19.3	50.2	-27.0
LeGrand	44.0	5	5	4	38.1	0.2	16.1	44.9	-16.2
Livingston	25.1	1	3	1	43.7	1.5	17.9	48.8	-22.2
Merced	18.3	1	3	1	42.6	1.7	19.7	54.2	-28.5
Mission (K)	64.8	10	8	10	48.4	1.3	17.5	45.6	-19.8
Mono	17.7	1	2	1	39.0	1.5	16.1	45.9	-16.1
Monterey (K)	32.9	6	7	9	47.1	1.1	18.4	48.3	-23.6
Ne Plus Ultra	10.0	5	9	6	51.0	1.8	16.9	43.8	-17.3
Nonpareil	6.0	2	1	1	42.4	2.3	16.7	47.0	-17.8
Padre (K)	17.5	7	6	7	44.2	1.0	18.6	49.9	-24.7
Peerless	11.5	4	6	5	48.2	2.0	18.2	48.2	-22.7
Price	16.7	5	2	1	41.4	2.2	17.2	48.6	-19.7
Ruby (K)	26.7	3	8	2	48.8	1.4	19.2	49.9	-26.5
Sauret I	22.0	3	3	2	42.2	2.0	17.3	48.3	-19.9
Sauret II	29.6	7	5	8	43.2	1.8	18.0	49.5	-22.2
Solano	34.4	5	1	6	42.0	1.3	17.1	47.2	-19.3
Sonora	10.7	3	1	3	48.3	1.4	16.7	43.8	-16.8
Thompson (K)	21.5	3	3	3	51.0	0.8	17.1	43.2	-17.7
Tokyo (K)	24.2	1	1	1	45.7	2.2	18.4	50.0	-23.8
Yosemite	36.5	4	5	4	39.3	1.7	15.9	45.7	-15.6
LSD (5%)	----	--	--	--	2.1	0.3	0.8	2.1	2.8

[z] Varieties labeled with a (K) or (WSFS) were harvested from Kern County RVT and West Side Field Station, respectively; all others were picked from Delta College RVT.
[y] 1 = easy to 10 = difficult
[x] 1 = thin to 10 = thick
[v] 1 = much swelling to 10 = little swelling

Table A-5. Mean sensory evaluation data (n = 33) of raw natural kernels of 23 almond varieties.

	Sensory evaluation scores[y]				
Variety[z]	Sweetness	Almond flavor intensity	Off-flavor	Firmness	Crispness
Butte	4.7	4.5	1.6	6.3	5.5
Carmel	5.2	7.0	1.5	6.4	6.0
Fritz (K)	4.7	6.7	1.8	7.1	7.0
Jeffries (WSFS)	5.1	5.3	1.5	7.4	7.1
LeGrand	-------------------	no data collected	--------------------		
Livingston	5.3	7.2	2.3	6.7	4.2
Merced	5.3	6.1	2.1	6.2	5.3
Mission (K)	5.8	7.0	1.2	7.1	6.8
Mono	5.3	5.4	2.0	7.2	4.8
Monterey (K)	5.8	6.6	1.4	7.3	6.7
Ne Plus Ultra	4.9	6.3	1.9	6.6	6.4
Monpareil	5.1	5.7	1.5	6.4	6.5
Padre (K)	5.1	5.6	2.2	7.2	7.3
Peerless	4.7	5.2	2.0	7.3	7.2
Price	4.7	4.9	2.9	6.5	4.8
Ruby (K)	4.6	5.3	2.8	8.1	7.6
Sauret I	5.2	7.6	1.2	7.7	7.7
Sauret II	5.1	7.4	1.9	5.5	4.7
Solano	5.0	5.5	1.5	6.6	7.4
Sonora	5.5	6.0	1.4	5.6	6.1
Thompson (K)	5.3	6.2	1.9	7.5	7.7
Tokyo (K)	4.8	6.7	2.7	7.9	7.5
Yosemite	5.1	5.0	2.8	7.8	7.3
LSD (5%)	0.8	0.9	0.8	0.8	0.9

[z]Varieties labeled with a (K) or (WSFS) were harvested from Kern County RVT and West Side Field Station, respectively; all others were picked from Delta College RVT.
[y]1 = least to 10 = most

Table A-6. Mean sensory evaluation data (n = 33) of roasted kernels of 23 almond varieties.

Variety[z]	Sensory evaluation scores[y]				
	Sweetness	Almond flavor intensity	Off-flavor	Firmness	Crispness
Butte	5.2	5.3	1.7	6.7	7.9
Carmel	5.2	6.0	1.6	6.6	8.0
Fritz (K)	4.5	4.8	2.4	5.0	7.9
Jeffries (WSFS)	5.5	5.6	1.5	6.7	8.0
LeGrand	--------------------- no data collected -------------------				
Livingston	4.4	4.6	2.3	7.2	8.1
Merced	5.3	4.9	1.7	6.4	8.4
Mission (K)	4.6	5.1	2.1	5.9	8.3
Mono	4.9	5.3	1.9	6.8	7.8
Monterey (K)	5.6	5.3	2.2	5.9	8.2
Ne Plus Ultra	4.8	5.8	1.5	6.2	8.6
Nonpareil	4.8	5.8	1.7	6.3	8.1
Padre (K)	5.1	5.0	2.4	5.7	8.0
Peerless	4.7	5.2	1.5	5.7	8.5
Price	4.1	5.2	1.9	7.0	7.8
Ruby (K)	5.1	5.6	2.8	6.6	7.5
Sauret I	5.2	5.5	1.8	6.3	8.2
Sauret II	5.1	5.7	1.9	6.2	8.4
Solano	5.4	5.7	1.6	5.3	8.0
Sonora	5.5	6.0	1.6	5.9	8.3
Thompson (K)	5.1	5.3	1.8	5.3	8.4
Tokyo (K)	5.0	5.6	1.8	6.0	7.9
Yosemite	4.7	4.8	2.1	6.3	7.9
LSD (5%)	0.8	0.7	0.7	0.7	0.5

[z]Varieties labeled with a (K) or (WSFS) were harvested from Kern County RVT and West Side Field Station, respectively; all others were picked from Delta College RVT.

[y]1 = least to 10 = most.