Vitis 36 (1), 7–10 (1997)

Varietal differences in the texture of grape berries measured by penetration tests

by

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S u m m a r y : Penetration tests were made on 8 mm thick flesh sections from grape berries of 22 cultivars of *Vitis vinifera* L. and 18 of *Vitis labruscana* Bailey. Deformation at the first major peak (DFP), maximum force (MF), force at the first major peak (FFP) and work to the first major peak (WFP) were recorded. High correlation coefficients were obtained between the rating of difficulty of breakdown on mastication in the sensory tests and DFP (r=0.86**), and the rating of flesh firmness in the sensory test and MF (r=0.84**). The mean value and variance of DFP and WFP were significantly higher in *V. labruscana* than in *V. vinifera*, whereas those of MF were nearly the same. DFP and MF were not correlated for *V. vinifera* cultivars, but were for *V. labruscana* cultivars (r=0.68**). These results indicate that the texture of *V. labruscana* had a wide variation in toughness whereas that of *V. vinifera* was brittle and did not have a wide variation in toughness; both groups had the same variation in firmness.

K e y w o r d s : table grape, flesh texture, flesh firmness, varietal differences.

Introduction

Texture is one of the most important factors determining eating quality of table grapes. Many studies on fruit texture using instrumental measuring methods were reported on apple (FUKUDA *et al.* 1980; FUKUDA and KUBOTA 1981; ABBOTT *et al.* 1984; ABBOTT 1994), European pear (BOURNE 1968) and Japanese pear (MACHIDA and MAEDA 1966; MACHIDA and TASHIRO 1968). Fruit firmness has been measured using the Magness-Taylor fruit pressure tester in the Japanese pear breeding program of the National Institute of Fruit Tree Science (NIFTS), Japan (MACHIDA and KOZAKI 1975, 1976).

There is a large difference in grape texture between *Vitis vinifera* L. and *Vitis labrusca* L. (GALET 1979). BOURNE (1979) reported on especially distinctive differences in the difficulty of breakdown on mastication between the flesh texture of both species. BOURNE also suggested that the difficulty of mastication of *V. labrusca* flesh was probably the reason for its comparatively small consumption as table grapes. Flesh firmness is an important part of grape texture because firm flesh signifies freshness to a customer (BERNSTEIN and LUSTIG 1981). Various terms to describe grape texture have been used (HEDRICK 1925; SLATE *et al.* 1962; GALET 1979), and no common texture usage is available. Only few reports are available on varietal differences of the mechanical porperties of grape texture (e.g. DÜRING and LANG 1990). BERNSTEIN and LUSTIG (1981, 1985) measured flesh firmness of some *V. vinifera* grapes as related to water potential and shipping quality.

Our objectives were to express grape texture by instrumental measurements and to describe variation of flesh texture among grape cultivars by these measured values.

Materials and methods

A total of 40 table grape cultivars with a wide range of variation in flesh texture grown at the Persimmon and Grape Research Center, National Institute of Fruit Tree Science (NIFTS), were used in the study: 22 of *V. vinifera* L., and 18 of *V. labruscana* Bailey (Tab. 1).

One bunch of each cultivar was harvested at its respective ripening time. Ten berries were randomly chosen from each bunch, and an 8 mm thick flesh section was cut longitudinally from each berry. Sections were subjected to a penetration test using a Rheometer (NRM-2010, Fudo Inc., Tokyo, Japan), at a penetration rate of 50.0 mm/min with a 3 mm diameter plunger. The test was performed on each cultivar either in 1993 or in 1994.

The force-deformation curve was recorded by an X-Y recorder (Fig. 1). The deformation axis (X) of the chart in this recorder was driven at 200 mm/min, exactly 4 times the speed of the penetrating rate. The force axis (Y) was determined at 1.96 N as 200 mm. The value of maximum force (MF), force at the first major peak (FFP), deformation at the first major peak (DFP), and work to the first major peak (WFP) were obtained from the force-deformation curve. DFP was calculated as 1/4 of the direct value on the chart. MF was given as the direct value. FFP was obtained to calculate WFP. WFP is expressed as an area under the curve to DFP, and is approximately equal to the triangle area: (DFP x FFP)/2. If FFP is equal to MF, WFP will be (DFP x MF)/2 (Fig. 1 B, C).

MF has been used as an indicator of flesh firmness (BOURNE *et al.* 1966). The term "brittle" was defined as the texture property manifested by a tendency to crack, fracture or shatter without substantial deformation after the

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Table 1

Grape cultivars examined: The varietal differences of texture by penetration test and description of texture

	Cultivar, species	Description of texture
	V. vinifera	
1	Alphonse Lavallée	slightly fleshy[z]
2	Black Hamburg	firm[y]
3	Cardinal	firm[y], fleshy[z]
4	Centennial	
5	Chasselas Rose	melting[z]
6	Emperor	firm, crisp[y], fleshy[z]
7	Flame Seedless	very firm, crisp[x]
8	Hiro Hamburg	
9	Italia	fleshy[z]
10	July Muscat	
11	Katta Kurgan	
12	Malaga	firm, crisp[y], fleshy[z]
13	Mission	firm, crisp[y]
14	Muscat Hamburg	tender, meaty[y]
15	Muscat of Alexandria	firm, crisp[y], fleshy[z]
16	Neo Muscat	
17	Perlette	fleshy[z]
18	Pizzutello Bianco	
19	Rish Baba	
20	Rizamat	
21	Rosaki	fleshy[z]
22	Sekirei	
	V. labruscana	
23	Bath	tender, soft[w]
24	Buffalo	tender[w]
25	Campbell Early	coarse[y]
26	Concord	tough[y], pulpy[z]
27	Delaware	tender[y], pulpy[z]
28	Fujiminori	
29	Hanover	tough[w]
30	Himrod	tender[w]
31	Kyoho	
32	Muscat Bailey A	
33	Naples	tough[w]
34	New York Muscat	slightly tough[w]
35	Niabell	
36	North Red	
37	Romulus	tender[w]
38	Ryuho	
39	Schuyler	tender, melting[w]
40	Steuben	slightly tough[w]

[z] GALET (1979)
[y] HEDRICK (1925)
[x] WEINBERGER and HARMON (1974)
[w] SLATE *et al.* (1962)

application of force (JOWITT 1974). The texture of food with low deformation is brittle. Therefore, DFP was used as an indicator of brittleness in this study. The area under the force-deformation curve measures the work done during a test. Work necessary to break (i.e. WFP) has been used as an indicator of toughness in the force-deformation curve (MOHSENIN 1982).

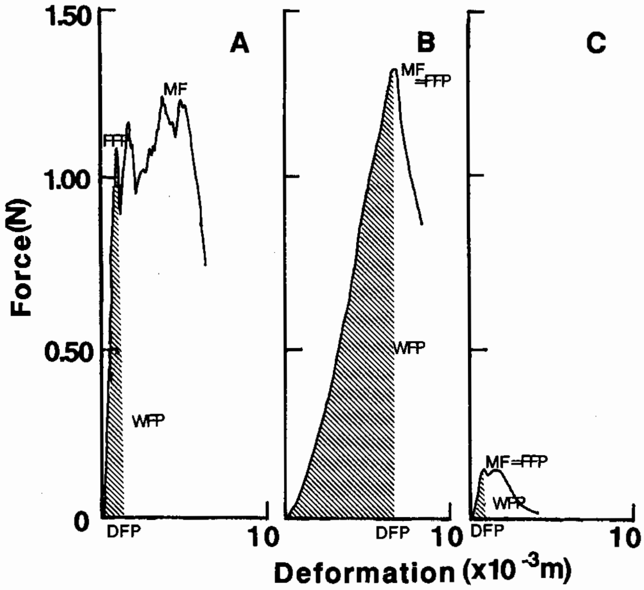

Fig. 1: Force-deformation curve of Cardinal (A); Hanover (B); Muscat Hamburg (C). DFP, MF and WFP: see Tab. 2; FFP: force at the first major peak.

In 1993, the flesh texture of 21 cultivars expressed as the combination of MF and DFP was compared with the classification of flesh texture by a sensory test. In the latter test, two panelists, well-trained grape breeders in NIFTS, classified flesh texture in terms of two factors, flesh firmness and difficulty of breakdown on mastication as follows: Firmness and difficulty of breakdown were rated on a 1 to 5 scale: 1=soft to 5=firm, and 1=easy to 5= difficult, respectively. Standard cultivars for firmness were: Muscat Hamburg (1), Steuben (3), Flame Seedless and Campbell Early (5). Standard cultivars for difficulty of breakdown were Rizamat and Flame Seedless (1) Kyoho (3), Hanover and Concord (5).

The MF, DFP and WFP values were also compared with other sensory evaluation of flesh texture described in the literature of HEDRICK (1925), SLATE *et al.* (1962), WEINBERGER and HARMON (1974), GALET (1979) (Tab. 1).

Results and Discussion

Correlation coefficients were calculated between the values obtained from the sensory test and those from the instrumental measurements. High correlation coefficients were observed between the rating of difficulty of breakdown on mastication in the sensory test and DFP (r=0.86**), and between the rating of flesh firmness in the sensory test and MF (r=0.84**). Therefore, the variation in difficulty of breakdown and flesh firmness could be largely measured by DFP and MF values, respectively.

All DFP, MF and WFP data were transformed logarithmically because the mean of the cultivar and SD were correlated. The model of variance (ANOVA) in one-way classification was made to estimate genetic variance (the variance between cultivar: σ_G^2) and error variance (σ^2).

Table 2

Mean and variance of deformation at the first major peak (DFP), maximum force (MF) and work to the first major peak (WFP) of *V. vinifera* and *V. labruscana* cultivars

Species	Number of cultivars	DFP (m) Mean[z]	DFP (m) Variance[y]	MF (N) Mean	MF (N) Variance	WFP (J) Mean	WFP (J) Variance
V. vinifera	22	0.0019a	4.2×10^{-7}a	0.654a	0.082a	0.0006a	2.5×10^{-7}a
V. labruscana	18	0.0045b	3.3×10^{-6}b	0.771a	0.101a	0.0019b	1.6×10^{-6}b

[z] Mean separation for DFP and WFP by Cochran's t-test, P=0.01, and mean separation for MF by Student's t-test, P=0.01.

[y] Variance separation by F-test, P=0.01.

Means followed by the same letter within a column are not significantly different.

The model of ANOVA in one-way classification could be assumed because the distribution of residue approached to normal distribution at P=0.05 by the Kolmogorov-Smirnov one sample test (Campbell 1974). ANOVA revealed that the effect of the cultivar was significant at P=0.01. ANOVA also estimated the genetic variance. The ratio of genetic variance to total variance shown as $\sigma_G^2/(\sigma_G^2 + \sigma^2/10)$ (10 berries of each cultivar) were 0.98, 0.96 and 0.97 for DFP, MF and WFP, respectively, indicating the small environmental variation for the mean value of each cultivar.

The value of DFP in the group of *V. vinifera* cultivars was limited to less than 4 mm whereas the group of *V. labruscana* showed a wide variation in DFP ranging from 0.8 to more than 7.2 mm (Fig. 2). The mean value and variance in DFP was significantly higher for *V. labruscana* (4.5 mm and 3.3×10^{-3}, respectively) than for *V. vinifera* (1.9 mm and 4.2×10^{-4}, respectively) (Tab. 2). Since DFP is an indicator of "brittleness" (Jowitt 1974), these results mean that the flesh *of V. vinifera* was generally more brittle than that of *V. labruscana*. Both groups, however, showed nearly the same variation for MF indicating flesh firmness (Tab. 2). The mean value and variance in WFP was significantly higher in *V. labruscana* (0.0019 J and 1.6×10^{-6}, resp.) than in *V. vinifera* (0.0006 J and 2.5×10^{-7}, resp.; Tab. 2), similar to those in the DFP.

The DFP was significantly correlated with the MF for *V. labruscana* cultivars (r=0.68**), whereas it was not correlated for *V. vinifera* cultivars (r=0.01). DFP and MF thus are linked only for *V. labruscana* cultivars (Fig. 2). The flesh texture of *V. labruscana* has been referred to either "tough" or "tender" (the antithesis) (Tab. 1 and Fig. 2). Sensory toughness classified by Hedrick (1925) and Slate *et al.* (1962) in 12 cultivars (Tab. 1) was highly correlated with the WFP (r_s=0.82**; r_s: Spearman's rank coefficient, Siegel 1983), indicating that the WFP value successfully expressed the toughness (Fig. 3). The FFP value was highly correlated to DFP (r=0.93**) in *V. labruscana* cultivars in this study, indicating that WFP one-dimensionally measures the variation of the flesh texture in *V. labruscana* cultivars, combining FFP and DFP. This may explain why the texture of *V. labruscana* has been classified as "tough" or "tender". Here, the FFP value was equal to the MF value in 83 % of *V. labruscana* cultivars, therefore, DFP was correlated with MF (Fig. 2).

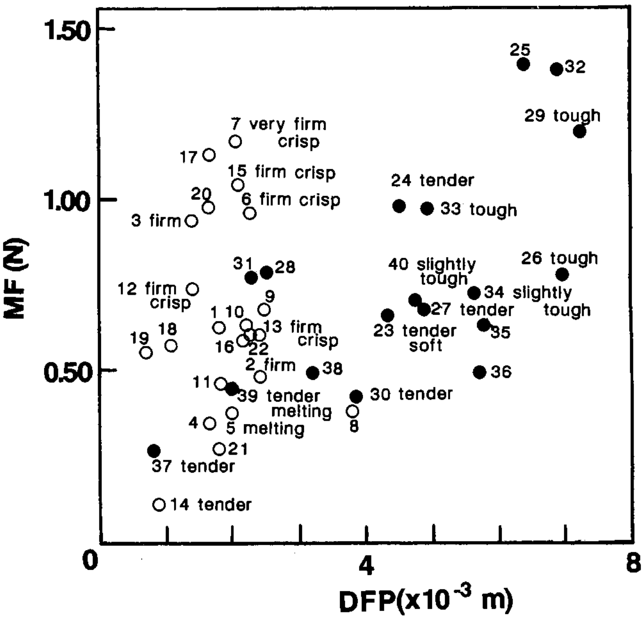

Fig. 2: Relationship between the DFP and the MF of 40 grape cultivars. ○ and ● indicate *V. vinifera* and *V. labruscana*, respectively. Correlation coefficients between DFP and MF in *V. vinifera* and *V. labruscana* are 0.01[NS] and 0.68**, respectively. See Tab. 1 for cultivar nos. and Tab. 2 for DFP and MF.

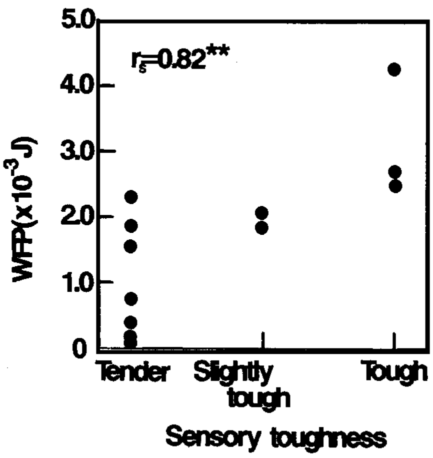

Fig. 3: Relationship between the sensory toughness and the WFP of 12 cultivars. Sensory toughness was classified by Hedrick (1925) and Slate *et al.* (1962) into tender, slightly tough and tough. Correlation coefficient (r_s) was calculated based on Spearman's rank correlation (Siegel 1983). WFP: see Tab. 2.

The flesh texture of *V. vinifera*, on the other hand, has not been expressed as "tough" or "tender", but as "crisp" or "non-crisp", or "firm" or "soft" (Tab. 1 and Fig. 2). *V. vinifera* cultivars have generally low DFP with a narrow variation, therefore, the variation in the flesh texture in these cultivars may have been expressed solely on the basis of firmness. None of them could be classified as "tough" using the above definition because no cultivars with high DFP were found.

STERLING and SIMONE (1954) defined "crispness" as 1) the quality of fracturing under relatively slight distortion, hence "brittle", or 2) the quality of fracturing into many small pieces under compressive pressure. The former property can be expressed as low DFP. Sensory crispness is closely linked to hardness in apple (ABBOTT *et al.* 1984) and in almond (STERLING and SIMONE 1954). Assuming the firm and easy to breakdown texture as "crisp", a crisp texture can be viewed as the combination of high MF and low DFP. Consistent with that, our results indicated that the texture of *V. vinifera* cultivars with high MF and low DFP had been expressed as "crisp" (Tab. 1 and Fig. 2).

The texture of some cultivars combining low MF and DFP was expressed as "melting" in the literature (Tab. 1 and Fig. 2); this may convey a texture affected by juiciness. Usage of this term should be further elucidated by a more inclusive study related to the DFP and MF.

A crisp texture is generally preferred by consumers. One of the important objectives in the grape breeding program of NIFTS, Japan, is to release disease resistant cultivars having large berries and a crisp texture. The genes of resistance to diseases like anthracnose or downy mildew must be derived from *V. labruscana*, which does not have a crisp texture. Crosses have been made between *V. vinifera* and *V. labruscana* in the program. But the present study indicated that DFP and MF were linked in *V. labruscana* cultivars although the correlation coefficient between them was not extremely high (0.68).

This suggests that a few offsprings with the crisp texture can be obtained from those crosses. Quantitative and genetic analyses of DFP and MF for the segregation of offsprings from those crossings will provide important information on the breeding strategy.

In conclusion, use of DFP and MF allowed instrumental and quantitative measurement of the difficulty in breakdown and flesh firmness of cultivars, and expressed the differential features of flesh texture as tough, tender, crisp, firm and soft among grape cultivars.

References

ABBOTT, J. A.; 1994: Firmness measurement of fleshy harvested "Delicious" apples by sensory methods, sonic transmission, Magness-Taylor, and compression. J. Amer. Soc. Hort. Sci. **119**, 510-515.

- -; WATADA, A. E.; MASSIE, D. R.; 1984: Sensory and instrument measurement of apple texture. J. Amer. Soc. Hort. Sci. **109**, 221-228.

BERNSTEIN, Z.; LUSTIG, I.; 1981: A new method of firmness measurement of grape berries. Vitis **20**, 15-21.

- -; - -; 1985: Hydrostatic methods of measurements of firmness and turgor pressure of grape berries. Sci. Hort. **25**, 129-136.

BOURNE, M. C.; 1968: Texture profile of ripening pears. J. Food Sci. **33**, 223-226.

- -; 1979: Texture of temperate fruits. J. Texture Study **10**, 25-44.

- -; MOYER, J. C.; HAND, D. B.; 1966: Measurement of food texture by a universal testing machine. Food Technol. **20**, 522-526.

CAMPBELL, R. C.; 1974: Statistics for Biologists. 2nd ed., 183-196 [Japan.]. Baifukan, Tokyo.

DÜRING, H.; LANG, A.; 1990: Grape berry splitting and some mechanical properties of the skin. Vitis **29**, 61-70.

FUKUDA, H.; CHIBA, K.; KUBOTA, T.; 1980: Changes in texture properties of apple fruit by softening or the onset of mealiness. I. Relationship of universal testing machine parameters and Magness-Taylor reading to fruit softening.[Japan.]. Bull. Fruit Tree Res. Sta. **C7**, 33-47.

- -; KUBOTA, T.; 1981: Changes in texture properties of apple fruit by softening or the onset of mealiness. II. Anatomical aspects of crushed flesh tissue by compression and mastication.[Japan.]. Bull. Fruit Tree Res. Sta. **C8**, 31-41.

GALET, P.; 1979: A Practical Ampelography. Cornell Univ. Press, Ithaca and London.

HEDRICK, U. P.; 1925: Systematic Pomology. The Macmillan Company, New York.

JOWITT, R.; 1974: The terminology of food texture. J. Texture Study **5**, 351-358.

MACHIDA, Y; KOZAKI, I.; 1975: Quantitative studies on the fruit quality for Japanese pear (*Pyrus seroting* REHDER) breeding. I. Statistical analyses of cultivar populations. [Japan.]. J. Japan. Soc. Hort. Sci. **44**, 235-240.

- -; - -; 1976: Quantitative studies on the fruit quality for Japanese pear (*Pyrus seroting* REHDER) breeding. II. Statistical analyses of a hybrid seedling population.[Japan.]. J. Japan. Soc. Hort. Sci. **44**, 325-329.

- -; MAEDA, M.; 1966: Studies on the texture of pear fruit. II. Factors responsible for the texture in Japanese pear varieties. Part I. Fruit firmness and density of stone cell cluster. [Japan.]. Bull. Hort. Res. Sta. **A5**, 121-129.

- -; TASHIRO, T.; 1968: Studies on the texture of pear fruit. II. Factors responsible for the texture in Japanese pear varieties. Part II. Cell wall substances.[Japan.]. Bull. Hort. Res. Sta. **A7**, 93-110.

MOHSENIN, N. N.; 1982: Physical Properties of Plant and Animal Materials.[Japan.] Korin, Tokyo.

SIEGEL, S.; 1983: Nonparametric Statistics for the Behavioral Siences. [Japan.]. McGraw-Hill Book, Tokyo.

SLATE, G. S.; WATSON, J.; EINSET, A. J.; 1962: Grape varieties. Introduced by the New York State Agricultural Experiment Station. 1928-1961. N. Y. Agr. Expt. Sta. Bull. **794**, 35-47.

STERLING, C.; SIMONE, M. J.; 1954: Crispness in almonds. Food. Res. **19**, 276-281.

WEINBERGER, J. H.; HARMON, F. N.; 1974: "Flame Seedless". HortScience **9**, 602.

Received August 27, 1996