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Mineral Analysis from Corkspotted and Normal 'Anjou' Pear Fruit

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Abstract. **Relationships between mineral content and corkspot in 'Anjou' pears *(Pyrus communis)* were evaluated in 1985 and 1986. Although there were no significant relationships between mean preharvest fruit mineraI content and corkspot incidence, the postharvest mineral concentrations of corkspotted and normal fruit were markedly different. Corkspotted and normal pear fruit had different Ca and N : Ca ratios in all types of subsamples (peels, opposing tangential slices with peels, opposing tangential slices without peels, cortical tissue plugs from the area next to the core, cortical tissue plugs from the area just inside of the peel, and the cores including seed), based on either dry or fresh weight. The dry-weight basis also revealed differences in Mg concentrations in both years and in B and K concentrations in 1986. Peel concentrations correlated with other tissues and were the easiest subsample to process. Corkspot was absent in either year, with a peel N: Ca ratio below 6.3. A computer model used mean Ca concentrations and standard deviations to estimate the percentage of pears in each orchard that were less than a given threshold level. When the overall average percentage of arbitrarily defined low-Ca pears was small (< 10%), it was difficult to predict the actual number of low-Ca pears from mean Ca concentrations. Therefore, it may not be realistic to expect strong correlations between mean Ca concentration and the incidence of disorders commonly encountered in Hood River, Ore. This situation occurred even when Ca concentrations of disordered and normal pears clearly differed.**

Preharvest fruit mineral analysis is commercially used in the United Kingdom (Sharples, 1980; Wailer, 1980) and New Zealand (Ferguson et al., 1979) to predict storability of apples. Apples likely to store poorly are marketed immediately. Although other elements are also important, the Ca concentration is the most useful predictor. Similar programs are possible for 'Anjou' pears in the Pacific Northwest, but important differences between pears and apples may alter the approach. Most 'Anjou' pears are cold-stored before they are marketed. A preharvest analysis may not be as necessary, since, unlike apples, 'Anjou' pears are not marketed immediately. A postharvest analysis would improve the logistics of the practice.

Due to large concentration differences among fruit tissues, whole-fruit sampling, minus only the seeds and stems, has been proposed for apples (Wailer, 1980). Others have shown that small plugs of cortical tissue removed from just below the peel surface give the best, and most consistently reproducible, indication of bitter pit susceptibility, especially where Ca sprays have been applied (Ferguson et al., 1979; Turner et al., 1977). Additional reports suggest that differences in the Ca concentration between the peels of unaffected and disordered fruit were greater in both apples (DeLong, 1936; Holland et al., 1975) and pears (Woodbridge, 1971) than differences found in other fruit tissues. Some of the discrepancies between fruit analyses conducted by different laboratories (Holland et al., 1975) may be due to sampling differences.

Calcium concentration is the index most related to apple disorders, but (K + Mg)/Ca, K/Ca, and N : Ca also have been used (DeLong, 1936; Perring and Preston, 1974; van der Boon, 1980b; Wailer, 1980; Wills et al., 1976). Calcium, N : Ca ratio, and fruit weight have been found to correlate with corkspot in 'Anjou' pears (Al-Ani, 1978; Mundel and Schaalje, 1988; Woodbridge, 1971). In England, a fresh-weight expression is used to minimize the effect of year-to-year differences between the dry weight contents of fruit tissues (Fidler et al., 1973), but others feel that a dry-weight expression is adequate (van der Boon, 1980a). When using ratios between elements, either fresher dry-weight expression produces the same result. Fruit samples that vary in size are difficult to evaluate due to the strong negative relationship between fruit Ca concentration and fruit weight (Perring and Jackson, 1975; Vaz, 1984).

Since elements begin to migrate along concentration gradients after harvest (Perring, 1984), concentrations of elements in fruit that have been stored briefly may be more equally distributed among tissues, thus strengthening relationships between tissue types. A postharvest evaluation may allow the use of tissues that are easier to analyze than the fruit cortex. Furthermore, if postharvest, nondestructive analyses (Righetti and Curtis, 1989) and segregation of desirable and undesirable pears becomes possible, detailed knowledge of postharvest mineral concentrations will be required.

The objectives of this investigation were to determine 1) which pear fruit tissue is most useful for a postharvest fruit analysis program, 2) which mineral indices might be useful in making postharvest storage decisions, 3) how to evaluate samples that vary in size, 4) if the expression of mineral concentrations on a dry- or fresh-weight basis alters interpretation, and 5) if disordered and normal fruit differ in mineral concentrations even though correlations between mean orchard mineral concentrations and disorder incidence are not apparent.

Materials and Methods

Orchard surveys. Twenty commercial 'Anjou' orchards near Hood River, Ore., were sampled during 1985 and 1986, 1 and 2 months and immediately before harvest in both years. Two fruit from each of 20 trees in each orchard were sampled, weighed, quickly washed in a mild detergent–chelating solution (liquinox-EDTA), and rinsed in distilled water to remove any contaminants. After the pears were washed at the laboratory, opposite tangential slices, including peel, were collected, freeze-dried, and ground to a homogeneous powder in a Waring blender. Total N was calorimetrically determined with an auto-analyzer after micro-Kjeldahl digestion (Schuman et al., 1973). Concentrations of 22 elements were determined using a Jarrel-Ash inductively coupled argon plasma (Waltham, Mass.) spectrometer,

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Dried tissue (1 g) was ashed at 500C for 6 hr and dissolved in 10 ml of 10% HC1. Concentrations were expressed on a dry- and fresh-weight basis.

After short-term (3 to 4 months) and long-term (6 to 7 months) storage, unripened fruit was analyzed for firmness, titratable acidity, soluble solids concentration (SSC), corkspot incidence, and the occurrence of other obvious disorders. Quality characteristics were then correlated with preharvest mineral concentrations. Several corkspotted and normal fruit were also analyzed after each of the two storage periods to determine if differences in mineral concentrations were apparent.

Packinghouse studies. A detailed evaluation of corkspotted and normal fruit was initiated to supplement the orchard surveys. In 1985 and 1986, fruit from each of five orchards passed through a commercial Hood River packing line (presizing) on the same day. Packout data for each orchard was provided by the packing company. One box each of unwaxed Extra Fancy-grade pears and unwaxed corkspotted culls were collected from each of the five orchards in both years. Extra Fancy pears meet the requirements for U.S. Extra No. l-grade winter pears (U.S. Dept. of Agriculture, 1955) and are defect-free, well-formed fruit that are mature, but not overripe. The fruit are graded before being sized. Several of these orchards were also part of the orchard surveys. Samples were collected on 18 Sept. 1985 and 25 Sept. 1986. At this time, the fruit had been kept at – lC for 2 to 3 weeks. Similarly sized Extra Fancy and corkspotted culls, representing the average size fruit for each orchard (determined by visual inspection), were collected and briefly (2 to 3 weeks) stored at – lC until processing was complete. Samples were weighed, washed, and rinsed as described above.

Two pears of about equal size were used to obtain enough material to adequately analyze each of the six individual subsample tissue types. Average pear size ranged from 363 to 665 g, depending on orchard. Figure 1 illustrates the sampling scheme for tissue types: cores, tangential slices with and without peels, the peel itself, interior cortical tissue plugs, and exterior cortical tissue plugs. The stem one-third of the pears was removed and discarded since the disorder predominates in the calyx end of the fruit (Fidler et al., 1973). Cores (including seeds) were removed in a 1.5-cm cylinder extending to the bottom of the coreline (Fig. 1). Four opposing tangential slices were then removed, two with and two without peels. The removed peels made up the fourth subsample. The remaining two slices were cut equatorially into 20-mm-thick sections. Three 7-mm-diameter cylindrical plugs (20 mm long) were removed from the area immediately adjacent to the core in each of the four sections of the sample. Three plugs were also removed from tissue immediately below the peel in each of the same four sections. Therefore, each cortical plug subsample was made up of 12 plugs. Five two-pear samples for both Extra Fancy and corkspotted classes were evaluated from each orchard. Thus, a total of 60 subsamples per orchard (30 spotted and 30 nonspotted) were analyzed." The fresh subsamples were dried at 60C and ground to a homogeneous powder in a Waring blender. Mineral analysis was as described above.

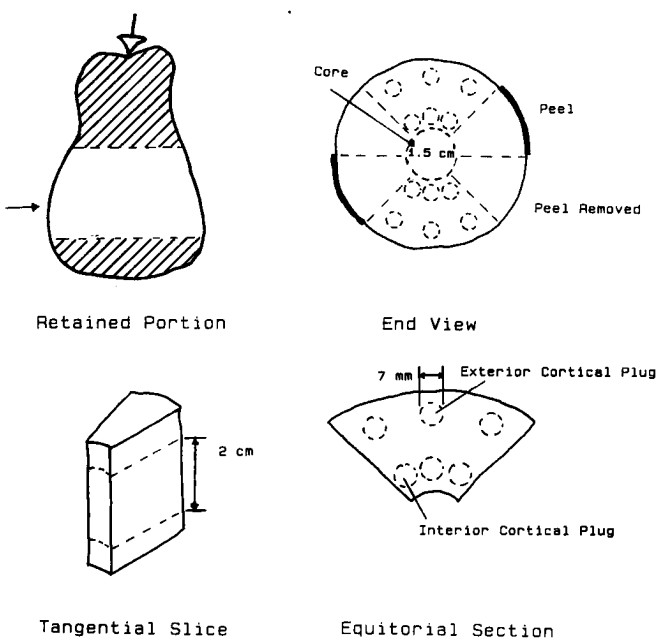

Fig. 1. Diagrammatic representation of subsampling scheme for packinghouse evaluations of Extra Fancy and corkspotted 'Anjou' pears.

Cortical plugs and longitudinal slices took up to 2 months to dry in our facilities. Furthermore, these tissues were hydroscopic when dry and had to be kept in a desiccator. However, peels dried in less than 1 week using a tunnel drier. In subsequent trials, peels were microwave-dried, allowing rapid (2 hr) processing without affecting the results.

The data for each type of subsample were analyzed as a two-factor factorial; five orchards and two conditions (disordered or not) with five replications. Each year was analyzed separately. Tissue types were compared using simple correlation and regression analyses. An analysis of covariance, with fruit fresh weight as a covariate, was also conducted for mineral concentrations and disorder incidence.

Computer simulations. Extra Fancy fruit from the five orchards in each year of the packinghouse study were assumed to represent the variability within and among orchards in the Hood River area. Standard deviations varied between orchards, but this variability was similar for both years. Since orchard standard deviations were calculated from five replicates using two pears per replicate, the standard deviation of an individual orchard was estimated from the following relationship (Little and Hills, 1978): $\sigma^2_{\bar{Y}} = \sigma^2/r$, where $\sigma_{\bar{Y}}$ = standard deviation of population means (calculated value), σ = standard deviation of the population (estimated value), and r = sample size on which the population of means is based (in this case 2).

A computer model used mean mineral concentrations and standard deviations to estimate the percentage of pears in each orchard that were either greater or less than given threshold levels. For example, when 600 ppm Ca was used as a minimum threshold, the incidence of low-Ca pears varied from 1.3% to 57.9%, with an average of 18.9%. These calculations were made assuming normal distributions. By arbitrarily altering threshold values, the average incidence (for all 10 orchards) of fruit having either high or low concentrations could be changed. Regression analysis was then used to relate mean mineral concentrations and standard deviations to the actual percentage of pears above or below arbitrarily established threshold levels.

Results and Discussion

Orchard surveys. Although correlations between N, Ca, and N : Ca ratios with quality characteristics have been significant in past studies conducted in the same general area (Vaz, 1984), this was not apparent in the two years' data we evaluated. Other mineral elements were also unrelated to quality components.

Separation of Extra Fancy from corkspotted fruit. Mean val-

ues for the concentrations of elements (N, Ca, B, K, and Mg) previously shown to be related to disorder incidence are listed in Tables 1 and 2. Other elements were never significantly different between fruit classes (data not shown). Fruit mineral concentrations in general were higher in. 1985 than 1986." There were mineral concentration differences between orchards. Mineral concentrations of corkspotted and Extra Fancy fruit classes also differ within orchards. However, pack out data from orchards with higher mean levels of Ca or lower N : Ca did not reveal less disorder incidence. Data based on fresh weight or dry weight led to similar interpretations, but, since differences based on fresh weight generally were at lower levels of significance, only dry weight data are presented.

Table 1. Nitrogen and Ca content and N : Ca ratios for the peel and cortex tissues of Extra Fancy and corkspotted 'Anjou' pears from five orchards in 1985 and 1986. Cortex tissue is from tangential slices without peels. All data based on dry weight.

	Extra Fancy fruit			Corkspotted fruit		
	N	Ca		N	Ca	
Tissue type	(ppm)		N : Ca	(ppm)		N : Ca
			1985			
Peel						
Orchard 1	5200	904	6.0	5600	728	8.6*
2	4400	1010	4.5	5000	810	6.7
3	6100	988	6.3	5500	519**	10.7**
4	3700	826	4.6	3900	773	5.4
5	4900	1020	5.0	4400	526**	9.1**
Mean	4900	949	5.3	4900	672**	8.1**
Cortex						
Orchard 1	4400	339	13.0	5600	289	19.9**
2	4000	532	8.2	4000	385**	10.8
3	5600	444	12.6	4900	272**	19.0**
4	3200	481	6.8	3500	391	9.5
5	4400	511	8.8	4000	279**	15.2**
Mean	4300	462	9.9	4400	323**	14.9**
Interior cortical plug	7200	775	9.6	6600	582*	12.2*
Exterior cortical plug	3600	450	8.5	3400	309*	12.6*
Core	13,500	1530	9.0	12,200	1210**	10.8
Tangential slice with peel	4600	578	8.2	4400	423**	11.4**
			1986			
Peel						
Orchard 1	5200	876	6.0	5000	354**	14.7**
2	4800	891	5.4	4400	288**	15.4**
3	4300	871	5.7	4100	356**	11.7**
4	3100	660	4.9	4000	393*	10.2**
5	4900	906	5.6	4700	569**	8.4*
Mean	4400	841	5.6	4400	391**	12.1**
Cortex						
Orchard 1	4400	474	9.6	4700	188**	26.1**
2	3700	398	9.7	3600	166**	21.5**
3	3800	453	9.2	4100	243**	17.1**
4	2700	368	8.1	3500	203**	17.2**
5	3900	462	9.0	4300	316*	14.2
Mean	3700	431	9.1	4000	223**	19.2**
Interior cortical plug	5600	674	8.8	5700	317**	18.5**
Exterior cortical plug	2800	398	8.5	3200	197**	15.7**
Core	10,800	1290	8.6	10,100	721**	14.7**
Tangential slice with peel	4000	554	7.5	4100	281**	15.7**

*,** Class means significantly different at $P = 0.05$ and 0.01, respectively, within orchards or tissues when not separated by orchard.

Table 2. Mean B and Mg content of six 'Anjou' pear tissue types for 1985 and 1986. (Pooled data, dry-weight basis, from five orchards.)

		Extra Fancy fruit		Corkspotted fruit	
Tissue type	Year	B	Mg	B	Mg
Interior cortical plug	1985	36.2	492	38.8	428*
	1986	30.3	446	25.6*	294**
Exterior cortical plug	1985	26.6	342	25.9	289*
	1986	21.9	365	18.5	263**
Core	1985	44.0	871	47.3	761*
	1986	38.7	634	33.0'	468*
Peel	1985	27.9	512	29.1	488
	1986	24.2	510	20.5"	409"
Tangential slice with peel'	1985	29.9	456	30.5	411*
	1986	24.7	458	21.7	363*
Tangential slice without peel	1985	30.0	415	29.9	359"
	1986	24.3	416	21.5	319*

*,** Class means within orchards are significantly different at P= 0.05 or 0.01, respectively.

Calcium concentrations provided the greatest separation between fruit classes for both years, in all fruit sample types, on either a fresh- or dry-weight basis. Nitrogen : calcium ratios were the next best mineral index for separating the quality classes in both years. The peel and the cortex tissue (tangential slices without peels) showed the greatest difference between classes using Ca concentration and N : Ca ratio (Table 1). This result was consistent for both years. With the exception in 1985 of orchard 4, in which even the corkspotted fruit that were graded in the packinghouse as unacceptable were only mildly and inconsistently affected with the disorder, there was virtually no overlap between fruit quality classes based on Ca content or N : Ca ratios of peel in either 1985 or 1986. While cortex (tangential slices without peels) analysis provided good separation of classes both years, there were more overlapping values. In 1986, neither cortex nor peel Ca and Ca : N ratios overlapped, and both provided a good degree of separation between corkspotted and the Extra Fancy classes. With the peels, one could designate a critical N : Ca ratio of 6.3, below which no corkspot occurred for either year, if one excludes orchard 4 in 1985. A consistent critical value is not apparent for cortex tissue. Since peel analyses are more convenient and provide a better separation between classes, they may be more useful than other tissues in a commercial program.

Magnesium concentrations on a dry-weight basis were significantly different between corkspotted and Extra Fancy fruit in all subsample types in 1985, with the exception of peel tissue. In 1986, the difference between the Mg concentrations of the two fruit classes was much greater, and all sample types showed significant differences between classes on both a dry- and a fresh-weight basis. Calcium and Mg concentrations were significantly correlated between all sample types. When combining both years' data, the relationship between Ca and Mg had r^2 values for peel and cortex tissue of 0.59 and 0.74, respectively. A reasonable separation would be possible using either Mg or N : Mg ratios. Relationships between Ca and Mg in the postharvest samples were much stronger than in preharvest samples (*r* values not significant for 1985 and 1986) of the same sample

type (tangential slices with peel). It remains to be determined if this is an anomaly or if Mg can be used as a Ca indicator in postharvest samples. Recent results from 1987 and 1988 also reveal a strong relationship between Mg and Ca in postharvest analyses of peels (data not shown).

Boron concentrations showed no significant differences between fruit classes with any of the pear sample types tested in 1985 on either a dry- or fresh-weight basis. In 1986, B concentrations differed significantly between classes on a dry-weight basis but not on a fresh-weight basis. Boron concentrations for fruit classes were not significantly different for all tissues (Table ,2). Potassium concentration differences between fruit classes were not evident in 1985 on either a fresh- or dry-weight basis. In 1986, K concentrations were only significantly different between classes in the interior cortex, the core, and the peel on a dry-weight basis for some individual orchards. The highest concentrations of K were in the interior cortical plug (=11,000 and 10,000 ppm for Extra Fancy and corkspotted fruit, respectively); the lowest concentrations were in the peel (=6500 and 6000 ppm for the two types of fruit, respectively). No significant differences between classes were found on a fresh-weight basis.

Nitrogen (Table 1) and B (Table 2) concentrations were highest in the core tissue, slightly lower in the interior cortex tissue, followed by peels, and the lowest concentrations were found in the exterior cortex tissue. Calcium concentrations were highest in the cores, lower in the peels, followed by interior cortical tissue, and lowest in the exterior cortex (Table 1). Potassium concentrations were highest in the interior cortex, lower in the core, followed by the exterior cortex, and generally lowest in the peels (Table 2). Magnesium concentrations were highest in the core, followed by peel tissue, and very similar in concentration in the exterior and interior portions of the cortex.

The correlation coefficients between mineral elements found in the peel and the same elements found in each of the other five types of subsamples are listed in Table 3. In general, there was a good relationship between tissue subsample types. High or low values in one subsample type were associated with high or low values in another. The comparisons were on a dry-weight to dry-weight basis. With few exceptions, correlations were all highly significant. Correlations between peel and cortex N or Ca concentrations in the postharvest samples were stronger than what we generally observe in preharvest relationships. Peel and cortex concentrations are usually significant, but the relationship was not exceptionally strong in preharvest samples (data not shown).

Mineral analyses for the peels and the cortex expressed on a dry-weight basis were strongly correlated with the same analyses expressed on a fresh-weight basis. The *r* values were always >0.90 for all elements. Similar relationships existed for the other tissues.

Relationships between sample weights and mineral concentration. An analysis of variance of sample weights found no significant differences between Extra Fancy and corkspotted fruit within individual orchards. Differences between orchards existed. An analysis of covariance comparing N, Ca, and N : Ca ratios between quality classes in peels and cortex subsample types, using sample fresh weight (fruit size) as a covariate, indicate that differences in fruit weight do alter mineral concentration, but this effect is not large. The weight-corrected means for the N and Ca concentrations and the N : Ca ratios within each orchard for each of the two classes are generally similar to those in Table 1. Fruit size did not affect the degree of separation between the classes of fruit. However, if one ranks the orchards on the basis of N : Ca ratios, with and without weight as a covariate, there are some slight changes in the ranking. Although there is a small effect of fruit size on mineral concentration, this can be accounted for with standard statistical procedures. Fruit weight was only weakly related to mineral concentration.

There appears to be more variability in mineral content within a given orchard than between the mean concentrations among them (Tables 1 and 2). For example, mean peel N : Ca ratios of Extra Fancy fruit (more than 80'% of the total) varied from 4.9 to 6.0 in 1986, while there were about. 2-fold differences between Extra Fancy and corkspotted fruit in each orchard. Even if weighted means are calculated using the percentages of Extra Fancy and corkspotted fruit from packout records, no relationship between mean mineral concentration and disorder incidence exists.

The large variability among fruit from a given orchard is a considerable problem. When distributions are different, it is possible for the actual number of fruit with high or low concentrations for a given element to be quite different in sampled orchards, despite similar mean concentrations. It may not be possible to correlate disorder incidence to mean concentrations for individual orchards. A poor correlation could occur even when the mineral concentrations of unaffected and affected fruit from the individual orchards are clearly different. Normal fruit consistently had significantly higher Ca than corkspotted fruit in the limited poststorage mineral analyses that were conducted on the survey samples (data not shown). Orchard variability likely explains why relationships between mean fruit Ca content in a given orchard and disorder incidence in the preharvest surveys were not significant.

Computer simulations. In general, the relationship between the mean mineral concentration and the percentage of pears either above or below an arbitrary threshold weakened as this percentage declined. This occurred for all the elements evaluated and was especially true for Ca, N, and N : Ca ratios. Figure 2 is a graphic presentation of how the strength of the relationship between mean Ca concentration and the percentage of low-Ca pears depends on the average incidence of low-Ca pears. When a threshold level of 450 ppm was used, the average incidence of low-Ca pears was =10%, with a range of 0% to 27%. It is apparent from Fig. 2 that <5090 of the variability in the incidence of low-Ca pears can be explained by differences in mean Ca concentration. The data shown was for peel concentration, but patterns are similar, regardless of the tissue used. In limited applications of the model to other fruits ('Red' and 'Golden Delicious' apple), similar results were obtained (unpublished data). At low incidence, the standard deviation is a much better predictor of the number of low-Ca pears in an orchard than the mean Ca concentration. A measure of variance may be more meaningful than mean concentration as an index of susceptibility to a disorder. In view of the difficulty in predicting the percentage of low-Ca pears from mean Ca concentrations as this percentage becomes low, it should not be surprising that predicting the incidence of a Ca-related disorder becomes even more difficult. From packout data, the incidence of corkspot for 1985 and 1986 varied from 0% to 30&, with an average incidence of < 5%. Average disorder incidence in the orchard surveys was also well under 10% in both years. Although these losses are economically important and segregating low- and high-risk orchards would be valuable, mean Ca concentrations may be of little use. Researchers have found significant relationships

Table 3. Correlation coefficients for mineral analyses of peel tissue vs. other tissue in 'Anjou' pears for 1985 and 1986. All mineral contents were compared on a dry-weight basis.[z]

	Peel vs.									
	Interior cortex plug		Exterior cortex plug		Core		Slice without peel		Slice with peel	
Element	1985	1986	1985	1986	1985	1986	1985	1986	1985	1986
N	0.85	0.86	0.69	0.84	0.88	0.77	0.85	0.88	0.90	0.89
Al	0.88	0.60	0.85	0.57	0.80	0.69	0.81	0.61	0.82	0.87
As	0.81	0.82	0.86	0.88	0.85	0.83	0.82	0.86	0.84	0.96
B	0.88	0.93	0.87	0.92	0.89	0.97	0.92	0.94	0.93	0.97
Ba	0.83	0.94	0.80	0.94	0.73	0.94	0.83	0.98	0.92	0.98
Ca	0.75	0.92	0.59	0.89	0.70	0.87	0.77	0.94	0.79	0.97
Cd	0.89	0.79	0.90	0.82	0.80	0.76	0.91	0.89	0.86	0.91
co	0.93	0.83	0.93	0.85	0.93	0.83	0.89	0.86	0.91	0.95
Cu	0.50	0.51	0.36	0.35	0.02	0.83	0.30	0.48	0.33	0.74
Fe	0.44	0.47	0.40	0.37	0.41	0.03	0.52	0.27	0.72	0.58
K	0.63	0.78	0.75	0.80	0.59	0.81	0.66	0.80	0.67	0.91
Li	0.04	0.19	0.18	0.61	0.22	0.11	0.11	0.03	0.23	0.08
Mg	0.60	0.84	0.52	0.77	0.50	0.49	0.54	0.85	0.73	0.94
Mn	0.85	0.80	0.81	0.77	0.72	0.67	0.80	0.83	0.90	0.93
Mo	0.90	0.81	0.11	0.87	0.92	0.80	0.91	0.88	0.91	0.95
Na	0.44	0.13	0.16	0.12	0.58	0.31	0.57	0.48	0.62	0.41
Ni	0.61	0.78	–0.11	0.79	0.72	0.73	0.73	0.84	0.51	0.94
P	0.74	0.76	0.28	0.63	0.56	0.52	0.65	0.76	0.71	0.88
s	0.56	0.51	0.39	0.43	0.28	0.32	0.57	0.57	0.64	0.74
Se	0.70	0.75	0.74	0.71	0.71	0.81	0.76	0.79	0.68	0.86
Sr	0.72	' 0.95	0.73	0.94	0.68	0.93	0.74	0.97	0.86	0.97
Zn	0.66	0.36	0.30	0.25	0.11	0.32	0.47	0.53	0.70	0.65

[z]Values > 0.44, 0.35, 0.27 significant at P = 0.001, 0.01, and 0.05, respectively.

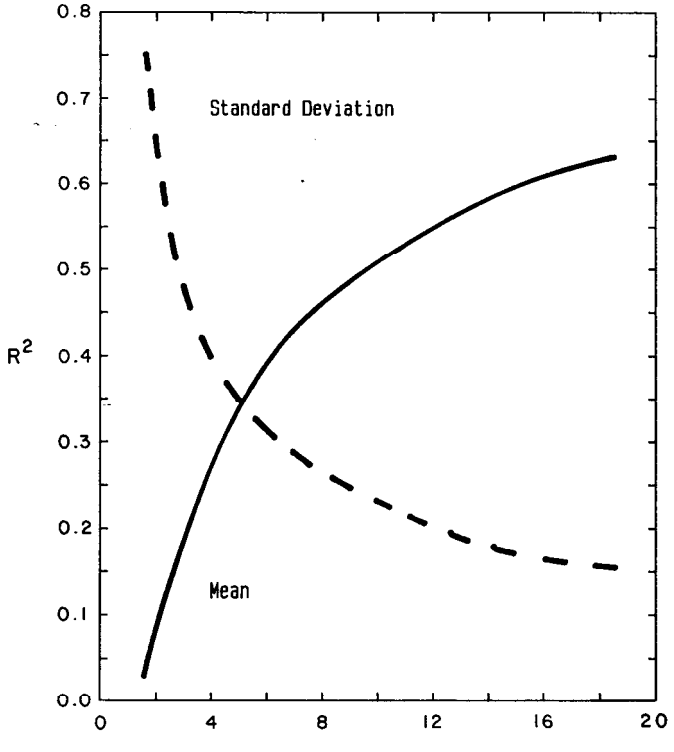

Fig.2. A graphic presentation of how the strength of the relationship (r^2) between either mean Ca concentration or standard deviation and the percentage of low-Ca pears depends on the average incidence of low-Ca pears.

between mean Ca concentrations and corkspot in 'd'Anjou' pears (A1-Ani, 1978; Vaz, 1984), but disorder incidence in these studies was usually higher than commonly occurs.

Recommendations. Ideally, one would like to correlate mean fruit analyses for a group of orchards with poststorage disorder incidence. However, the variability within orchards may obscure correlations even when disordered and normal fruit differ in mineral composition. For this reason, we concentrated on identifying the most appropriate tissue to separate Extra Fancy and corkspotted fruit.

All postharvest tissue mineral concentration levels that are generally associated with disorder occurrence are correlated to each other, suggesting that total fruit mineral content (which has been clearly related to post-storage disorder incidence) could reestimated by ananalysis of any of the tissues. Estimates of total fruit mineral content calculated from the relative proportion and concentration of the tissues sampled are clearly related to peel concentration (r^2 = 0.82). In view of other studies where preharvest minerals were related to postharvest storability (Al-Ani, 1978; Vaz, 1984), it is logical to expect similar relationships with postharvest samples. Mineral distribution within the fruit may change following harvest, but total mineral content does not change.

Low-Ca pears are likely to be more susceptible to storage disorders. Although not apparent in this study, high-N pears are also undesirable (A1-Ani, 1978; Raese et al., 1989). Efforts should be directed at developing approaches to estimate variability in an orchard and approximate the actual number of fruit with undesirable mineral concentrations. When disorder incidence is low, as it almost always is in northwestern fruit varieties, the orchard variability factor is far more important than

which type of fruit tissue, digestion or fractionation procedure, sample time, or method of mineral expression.

The peel may be the best tissue to evaluate. With peel N : Ca ratios, there was a clear threshold value below which corkspot did not occur, and this level (6.3) remained constant between years and orchards. The peel is also the easiest tissue to collect and conventionally analyze of the six tissues examined in this experiment.

Although identifying high-risk orchards is not always successful, there may be some merit in using mean mineral concentrations from either pre- or postharvest fruit testing programs. In some years for some regions where large differences in mean mineral concentrations occur and incidence of disorders is high, an economic benefit is probable. The small cost of analysis relative to the potential value of the crop makes analytical services attractive. Successful identification of potential storage problems even 1 year out of 5 represents huge financial savings.

Developing technology also makes postharvest analysis of peel tissue attractive. Nondestructive measurements of fruit mineral concentrations (Righetti and Curtis, 1989) would allow very rapid determinations and, thus, create the possibility of an automated sorting of low- and high-risk fruit.

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