CONTRIBUTIONS OF MACRONUTRIENT MINERAL CONCENTRATIONS IN FRUIT TO LOSSES OF MASSACHUSETTS APPLES AFTER STORAGE

William J. Bramlage, Sarah A. Weis, and Mack Drake
Department of Plant and Soil Sciences
University of Massachusetts
Amherst, MA 01003 USA
(Presented by W.J. Bramlage)

BRAMLAGE '82

Extensive studies in England quantified the influences of N, P, K, Ca, and Mg on fruit quality and the development of physiological disorders and rot after storage of apples and pears (8). Susceptibility to bitter pit, senescent breakdown, and Gloeosporium rot were negatively correlated with fruit Ca; susceptibility to bitter pit and rot were positively correlated with K/Ca and Mg/Ca ratios; fruit firmness was positively correlated with fruit P; low temperature breakdown was negatively correlated with fruitlet P. These studies led to recommended ranges of mineral levels for optimum storage of Cox's Orange Pippin apples, and to commercial prediction of storage life of these fruit from preharvest mineral analyses.

We have undertaken similar studies to determine if Massachusetts McIntosh apple storage life can also be predicted from mineral analyses. We report here the results of 2 years of surveys of commercial orchards to assess the quantitative influences of N, P, K, Ca, and Mg on characteristics of Massachusetts McIntosh apples after storage, and of an attempt to predict storage losses from mineral analyses.

In 1979-80, 34 commercial Massachusetts orchard blocks were sampled. We attempted to sample as diverse a group of blocks as possible, including different rootstocks, tree ages, McIntosh strains, and histories of problems. In some instances 2 or 3 different blocks in a given orchard were sampled since they represented different situations.

Approximately 2 weeks before commercial harvest began, 20 representative trees within each block were tagged and 1 fruit from each tree was taken for whole-fruit mineral analysis essentially according to Holland et al. (3). At the beginning of commercial harvest 2 bushels of fruit were taken from these same trees; 1 bushel was stored in 0°C air for 5 months, and the other was stored in 3.3°C CA storage (3% O_2, 5% CO_2) for 9 months.

1982. * CONT. ATMOS. FOR STOR. & TRANS. OF PERISH. AGRIC. COMMODITIES * RICHARDSON & MEHERIUK, Eds. - ORE. ST. UNIV.

Thus, all samples were harvested at about the same maturity and were stored in the same atmospheric conditions. Firmness was determined at harvest and 1 day after removal from storage, and disorders were counted after 1 week at room temperature (70–80°F) following storage. The 1980-81 survey included 25 orchards, in each of which both a block of trees on seedling rootstock and a block of trees on Malling 7 rootstock were sampled. Sampling, analysis, and storage were as in the previous year.

Perring's (7) summary of 20 years of analyses of Cox's Orange Pippin fruit mineral composition provides a comparison for the mineral levels of our commercial orchard samples (Table 1). Whereas our Mg levels were essentially identical to those of the English samples and our Ca levels covered about the same range, our P levels were somewhat lower and our K and especially our N levels were much lower. Furthermore, our Ca, N, K, and P levels were higher in 1980-81 than in 1979-80, probably due at least in part to somewhat smaller fruit the second year.

To assess relationships of these mineral levels to fruit characteristics after storage, correlation coefficients were calculated between firmness, senescent breakdown, rot (primarily due to Penicillium spp.) and superficial scald, and the whole-fruit concentrations of N, P, K, Ca, and Mg at harvest (Table 2). Bitter pit occurred too seldom to be considered.

The strongest relationships were the negative correlations between Ca and breakdown and Ca & rot.These were expected since we (1) and others (2) have consistently found that low fruit Ca levels are related to greater incidences of disorders after storage, There was also a strong negative relationship between Ca and scald after air storage, as we have sometimes seen previously (1).

High N and K concentrations can adversely affect fruit quality (2). Among our samples, the relationships of N to fruit quality were weak except for the negative correlation with fruit firmness at harvest in 1979 (Table 2). Relationships of K levels to fruit quality were also weak except for the positive correlation with scald after storage in 1979-80. These generally weak relationships probably reflect the relatively low fruit N and K levels in the samples (Table 1), which our commercial recommendations have been striving to achieve in recent years.

P concentrations in fruit were not correlated with any fruit characteristic in either year (Table 2), which is consistent with other research we have been conducting which has failed to associate fruit P levels with postharvest quality of McIntosh. This contrasts with studies in England (1, 4) and Australia (5), where low P has been associated with low temperature breakdown and soft fruit.

Mg was related to fruit firmness (Table 2) but since the relationship was negative in 1979-80 but positive in 1980-81, these correlations are probably either secondary or capricious. Mg concentrations in fruit appear to be very stable (Table 1).

Fruit firmness after storage is an extremely important quality factor for apples, especially an inherently soft cultivar such as McIntosh. In our samples there was no consistent relationship of mineral concentrations to fruit firmness. Greater firmness after storage has sometimes been found after Ca levels have been raised (6) but apparently the endogenous range of Ca levels does not normally affect McIntosh firmness.

Quantitative contributions of variations among these 5 minerals to variance in quality among the samples were determined by stepwise multiple regression (Table 3). By far the greatest effect was that of Ca on breakdown. N was the only other element significantly contributing to breakdown. Relationships of elements to occurrence of rot tended to weakly shadow the breakdown relationships. Both K and N concentrations contributed to scald incidence, and neither P nor Mg contributed significantly to any problem except for the strange Mg correlations with firmness.

It is interesting to note that in all cases, less total variance was accounted for by differences in mineral concentrations when CA fruit were examined than when air-stored fruit were examined. Thus, it appears that CA conditions may partially override the effects of adverse mineral concentrations in McIntosh apples.

Contributions of the 5 mineral elements to occurrences of disorders after storage are defined by the regression equations (Table 4). If these relationships are relatively constant from year to year, the regression equations can then be used as predictive indices for incidences of disorders. Since the strongest relationships were between minerals and senescent breakdown, we tested the 1979-80 regression equations as predictors of breakdown in the 1980-81 samples. In this prediction, we assumed that (1) the objective was to identify "high risk" samples before storage, not to predict the percent incidence of breakdown in each sample; and that (2) a "high risk" sample was one with the potential to develop breakdown in 10% or more of the fruit during a week at room temperature after storage. This value was chosen because it appears from previous data to be a natural break in arrays of commercial samples. Samples predicted to develop less than 10% breakdown were considered to possess "acceptable risk" for long-term storage.

The accuracy of these equations in predicting degree of risk is shown in Table 5. For air-stored fruit the equations were very effective predictors. Using the equation for Ca concentration alone, the prediction was correct for 48 of the 50 samples. When other elements were included the equations were less accurate, which is not surprising given the very weak contributions of N, P, K, and Mg to variance among these 1980-81 samples (Table 3), and the higher Ca concentrations in 1980-81 (Table 1).

For CA-stored apples the equations were not acceptable predictors of breakdown. The poor performance of the Ca-alone equation may have reflected the weaker relationship of Ca to CA breakdown in 1979-80 than in 1980-81 (Table 3), perhaps indicating the need for additional data to produce the appropriate equations. On the other hand, it might indicate that CA conditions override nutritional effects to an extent that accurate predictions of post-CA storage performance will not be possible.

In conclusion, these data suggest that among Massachusetts McIntosh orchards, variations in macronutrient concentrations in fruit are not contributing greatly to postharvest storage problems except for the adverse effects of low fruit Ca. This may reflect the efforts of these apple growers to maintain appropriate mineral levels in their crops and should not generate complacency. When samples were high in N and K, adverse effects usually occurred. Concentrations of most elements can change quickly from season to season, and other cultivars or other growing areas might possess stronger contributions of N and K to poststorage losses.

The successful prediction of susceptibility to senescent breakdown following air storage is encouraging to us, and we shall continue to test and attempt to refine the predictive indices for both air-stored and CA-stored apples.

Literature Cited

1. Bramlage, W.J., M. Drake, and J.H. Baker. 1979. Changes in calcium level in apple cortex tissue shortly before harvest and during post-harvest storage. Commun. Soil Science and Plant Anal. 10: 417-426.

2. Bramlage, W.J., M. Drake, and W.J. Lord. 1980. The influence of mineral nutririon on the quality and storage performance of pome fruits grown in North America. In: Mineral Nutrition of Fruit Trees. pp 29-39. Butterworths, Inc. London.

3. Holland, D.A., M.A. Perring, R. Rowe, and D.J. Fricker. 1975. Discrepancies in the chemical composition of apple fruits as analyzed by different laboratories. J. Hort. Sci. 50: 301-310.

4. Johnson, D.S. and N. Yogaratnam. 1978. The effects of phosphorus sprays on mineral composition and storage quality of Cox's Orange Pippin apples. J. Hort. Sci. 53: 171-178.

5. Letham, D.S. 1969. Influence of fertilizer treatment on apple fruit composition and physiology. 2. Influence on respiration rate and contents of nitrogen, phosphorus, and titratable acidity. Aust. J. Agric. Res. 20: 1073-1085.

6. Mason, J.L. 1979. Increasing calcium content of calcium-sensitive tissues. Commun. Soil Science and Plant Anal. 10: 349-371.

7. Perring, M.A. 1976. Fruit composition and the prediction of storage disorders of apples. Rep. E. Malling Res. Sta. for 1975: 169-170.

8. Sharples, R.O. 1980. The influence of orchard nutrition on the storage quality of apples and pears grown in the United Kingdom. In: Mineral Nutrition of Fruit Trees. pp. 17-28. Butterworths, Inc. London.

Table 1. Whole fruit mineral content (mg/100 g f. wt.) of English Cox's Orange Pippin apples and of Massachusetts McIntosh apples.

	Cox's Orange Pippin (20 year summary[z])		McIntosh 1979 - 1980		McIntosh 1980 - 1981	
	Mean	Range	Mean	Range	Mean	Range
Ca	5.0	3 - 8	4.4	2.8 - 6.6	5.5	4.0 - 8.7
N	65	40 - 100	24	12 - 35	37	21 - 48
K	135	100 - 200	95	66 - 116	106	82 - 131
P	13	8 - 20	9.7	6.8 - 11.7	10.7	6.4 - 13.6
Mg	5.2	4 - 7	5.4	4.5 - 6.2	5.3	4.6 - 6.4

[z]From Perring (7).

Table 2. Correlation coefficients for relationships between whole-fruit mineral analyses prior to harvest and characteristics of McIntosh apples. 1979-80. Values in parentheses are coefficients in 1980-81 that exceeded 0.29.

Characteristics and storage conditions[z]	Element Ca	N	K	P	Mg
Breakdown,					
Air stg	-.58(-.53)	+.28	+.28(+.32)	-.11	+.02
CA	-.34(-.48)	+.33	+.21	-.26	+.06
Rot,					
Air stg	-.41	+.29	+.14(-.30)	-.16	-.31
CA	-.34(-.32)	+.25	+.03	-.03	-.28
Scald,					
Air stg	-.38	+.33(+.33)	+.45	-.12	+.22
CA	-.20	+.30	+.33	-.07	+.24
Firmness,					
Harvest	+.05	-.45	+.04(+.35)	+.14	-.37(+.32)
Air stg	-.06	-.19	+.17	.00	-.38(+.36)
CA	+.11	+.11	+.03	+.29	+.01

[z]0°C air storage for 5 months, or 3.3°C CA storage (3% O_2, 5% CO_2) for 9 months.

Table 3. Percent of total variance within McIntosh apple characteristics after storage that could be accounted for by differences in concentrations of macronutrients in fruit at harvest, as determined by stepwise multiple regression.

Parameter		Element					
		Ca	N	K	P	Mg	Sum
Bkdn, Air,	'79	33***	5	1	5	0	44**
	'80	29***	4	6	2	0	41***
Bkdn, CA,	'79	12*	12*	4	9	1	38*
	'80	23***	6	0	1	1	31*
Rot, Air,	'79	17*	8	2	4	8	39*
	'80	6	6	9*	1	0	22NS
Rot, CA,	'79	12*	6	1	1	6	26NS
	'80	10*	1	0	1	0	12NS
Scald, Air,	'79	1	11	20**	14	2	48**
	'80	6	11*	4	0	0	21NS
Scald, CA,	'79	0	9	11	7	3	30NS
	'80	5	1	0	0	4	10NS
Firmness, Air,	'79	1	2	5	0	14*	22NS
	'80	2	0	1	2	13*	18NS
Firmness, CA,	'79	2	1	0	8	0	11NS

Significance at 0.5 level (*), .01 level (**), and .001 level (***).

Table 4. Regression equations describing the relationships between whole-fruit analyses for macronutrients (in ppm, fresh wt basis) and occurrences of senescent breakdown in McIntosh apples after 5 months of air storage at 0°C or 9 months of CA storage at 3.3°C plus 1 week at room temperature. 1979-80.

Air storage:

% breakdown = 49 - .92 (Ca)
= 38 - .88 (Ca) + .039 (N)
= 62 - .92 (Ca) + .047 (N) -.24 (P)
= 53 - .85 (Ca) + .049 (N) -.27 (P) + .0085 (K)
= 48 - .87 (Ca) + .048 (N) -.27 (P) + .0075 (K) + .12 (Mg)

CA storage:

% breakdown = 30 - .46 (Ca)
= 57 - .52 (Ca) - .26 (P)
= 47 - .47 (Ca) - .32 (P) + 0.58 (N)
= 22 - .29 (Ca) - .39 (P) + .063 (N) + .024 (K)
= 18 - .30 (Ca) - .39 (P) + .062 (N) + .023 (K) + .12 (Mg)

Table 5. Accuracy of predictions of senescent breakdown after air storage or CA storage of 1980-81 McIntosh samples, using 1979-80 regression equations.

Air storage		CA storage	
Elements included	% accuracy	Elements included	% accuracy
Ca	96	Ca	71
Ca + N	88	Ca + P	59
Ca + N + P	86	Ca + P + N	61
Ca + N + P + K	84	Ca + P + N + K	57
Ca + N + P + K + Mg	84	Ca + P + N + K + Mg	55