BIBLIOGRAPHY

1. American Bottlers of Carbonated Beverages, Members Information Bulletin, 1947.
2. CRUESS, W. V., AND IRISH, J. H. Fruit Beverage Investigations, Calif. *Agr. Expt. Sta. Bull.*, 359, 526-568. 1923.
3. IRISH, J. H.; Fruit Juice Concentrates. *Calif. Agr. Expt. Sta. Bull.*, 392, 1-20. 1925.
4. AREF, H., AND CRUESS, W. V. Observations on the Composition of Fruit Beverages. *Fruit Products Jour.*, 12, 228-229. 1933.
5. BAILEY, E. M. The Forty-First Report on Food Products. *Conn. Agr. Expt. Sta. Bull.*, 401, 863-866. 1937.
6. BAILEY, E. M. The Forty-Third Report on Food Products. *Conn. Agr. Expt. Sta. Bull.*, 426, 9-10. 1939.
7. BAILEY, E. M. The Forty-Fifth Report on Food Products. *Conn. Agr. Expt. Sta. Bull.*, 447, 452-6. 1941.
8. HEID, J. L. Concentrating Citrus Juices by the Vacuum Method. *Food Industries*, 15 No. 5, 62-4, 122; No. 6, 64-6. 110, 111. 1943.
9. J. J. R. BRISTOW. Personal Communication, 1947.
10. MOORE, E. L., ATKINS, C. D., WIEDERHOLD, E., MACDOWELL, L. G., AND HEID, J. L. The Concentrating and Drying of Citrus Juices. *Proc. Inst. Food Tech.*, 166. 1945.
11. STEVENS, J. W., AND BAIER, W. E. Refractometric Determination of Soluble Solids in Citrus Juices. *Ind. and Eng. Chem.*, 11, 447. 1939.
12. *Official Methods of Analysis of the Association of Official Agricultural Chemists*, 6ed, 26-28 (a), p. 390. 1945.
13. JACOBS, M. B. *Synthetic Food Adjuncts*, 1 ed., 66. D. Van Nostrand Co. 1947.
14. Ibid. p. 60.
15. DUNN, J. A. Salt and Its Place in the Food Industry. *Food Technology* 1, No. 3, 419. 1947.
16. JACOBS, M. B., *Synthetic Food Adjuncts*, 1 ed., 200. D. Van Nostrand Co. 1947.

INTERNAL FRUIT QUALITY AS RELATED TO PRODUCTION PRACTICES

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It has been suggested that a practical paper covering the relationship between internal fruit quality and production practices would be appropriate at this time. An attempt has been made to keep the discussion simple and at the same time present in a general way what are considered good technical contributions by various research workers in the field. To try to discuss all of the factors which are reported by fact and fiction to influence citrus 'maturity" and fruit quality would be a hopeless task in the time alloted. This represents only a humble attempt to try and correlate some of what we know, plus a few logical assumptions, with some of the practical concepts about citrus "maturity" and fruit quality.

It is to be regretted that our present maturity standards do not serve as a better criterion of taste and flavor of citrus juice. It has long been recognized that the ratio serves little more than a satisfactory index of sweetness and sourness. Work by Cowart (2) of the Citrus Experiment Station, shows that at any given degree of sweetness, total solids is the best criterion of flavor. A juice with low solids is weak and flat and lacking in character while high solids gives juice character and richness or "body." The results of this work indicate that both artificially adjusted juice and natural orange juice having less than 8.8 percent solids is not acceptable to taste and has very little flavor regardless of the variety or acid content. Oranges with soluble solids as low as 8.8 percent were of common occurence in Florida before the present fertilizer and spray programs using supplemental elements became widely accepted. The results of this work showed in general that with acceptable acidity, juice was considered fairly good with solids ranging from 8.8 to 10.0 percent, and good when the solids went above the ten percent level. The finest quality of juice was obtained where solids ranged about 13.00 percent accompanied by proper acid balance. The last figure is essentially representative of the midseason and late oranges now being generally produced within the State. Through the years it has become apparent that a careful analysis of fruit juices to determine their acid, sugar, soluble solids, vitamin C, juice content, etc. serves as a reasonably accurate index of fruit quality and further that such analysis can be used as a definite means of evaluating quality of fruits produced under varying conditions. The problem of determining the conditions which may affect changes in fruit quality becomes complex. There is a great deal of information about some of these conditions but in other cases data is insufficient or lacking entirely.

Weather Affects Fruit Quality

Many citrus growers have long recognized tthat weather conditions affect to a considerable extent the quality of the fruit which can be produced in any particular season. Fewer realize that weather conditions can cause differences in fruit quality as great or greater than can be induced by any culture or nutritional treatment which has thus far been used in citrus culture in Florida. Judging from the records at the Citrus Station during the past seven years, we have had two high solids years during this period. These were the 1940-41 and 1942-43 seasons. The fruit produced during the 1940-41 season was somewhat better than the latter, and was the only season during the past seven years when seedy grapefruit on rough lemon root-stock reached 10.00 percent total soluble solids by the latter part of September and approached 12.50 by the time it had reached prime quality condition. During the period from 1940 to 1944 there were two low and two high solids years. It would appear that differences caused by weather conditions which affect fruit quality should show up during this four year period. Oddly enough, no one element of weather is sufficiently outstanding from the study made thus far to enable one to say that it was the cause of the changes which have been noted. It would appear that these changes must be caused by a combination of weather factors rather than any one element of weather in particular. The high solids years, during the months of June, July, August and September are characterized by lower rainfall, a higher percentage of possible sunlight and a lower number of cloudy days. One of the high solids years (1940-41) had an early bloom; (approximately two to three weeks) the other did not. A check of the total available heat, according to the method suggested by Webber (14) failed to show any significant differences for the period in question. It is difficult to pick out elements of weather which affect fruit quality but the importance of these elements cannot be over-emphasized for much of the troubles we have been having with low solids Hamlin and Parson Brown oranges during the past few seasons is undoubtedly due to weather conditions. Increased knowledge of weather and how it affects physiological processes in citrus trees may in time permit predictions of some accuracy regarding the quality of fruit which may be expected under particular weather conditions.

There are a number of other factors affecting fruit quality concerning which information is more specific, and over which the grower can exercise much more control. The effect of root-stock has been investigated by Harding, Winston and Fisher (6) and by Harding and Fisher (7) and others. Only sour orange and rough lemon are commonly used as understocks in Florida at the present time to any extent. Under similar conditions, sour orange stock can be expected to produce fruit of better quality than rough lemon but the latter may mature fruit slightly earlier (5). The effect of arsenic on "maturity" and fruit quality is, of course, very important for grapefruit. This problem is at the present time being investigated further by Mr. Reitz at the Citrus Station and will be reported on at later date.

Fertilization as Related to Fruit Quality

Largely because of the critical situation which developed during the early thirties with regard to deficiences, investigations undertaken to determine their effects on growth production and fruit quality have been reported by a number of workers. Much has been done toward clarifying our knowledge of the effect of deficiencies of magnesium, manganese, zinc, and copper. The effect of these elements on the internal quality of citrus fruits has been reported by Cowart (3), Cowart and Stearns (4), Fudge and Fehmerling (5), Roy and Bahrt, (9), Skinner, Bahrt and Hughes (11), Sites (10), and Stearns and Sites (12). The results of these experiments have shown consistently the improvement in fruit quality which results from the correction of deficiencies of magnesium, manganese, zinc and copper. A deficiency of magnesium results in very marked decreases in soluble solids, acidity and vitamin C content, and it has been thoroughly demonstrated by plots at the Citrus Station that it is not possible to produce high quality fruit, maintain tree vigor or secure optimum production where a deficiency of magnesium exists. In view of the nature of some of the inquiries which have been received at the Citrus Station it is perhaps well to point out again certain facts with regard to the use of supplemental elements in the production of citrus so far as fruit quality is concerned.

A citrus tree by nature of its genetic constitution, its root-stock and its soil and climate environment has certain limitations in the quality of fruit which it can produce regardless of the nutritional and cultural treatment which it may receive. Once deficiencies of the supplemental elements are corrected and the grove is on a good maintenance program there is no reason to believe that application of these elements other than are needed for maintenance will improve internal fruit quality. There is no information to show that any benefits are derived from luxury consumption of these elements by citrus. Certainly there is no evidence from any of the nutritional plots at the Citrus Station that higher solids fruit can be produced from additional nutritional sprays or by increasing the percentage of these elements in the fertilizer mixture over and above those which are recommended for the maintenance of tree vigor. This is mentioned because of repeated inquiries as to the desirability of applying additional applications of magnesium, and the advisability of applying additional nutritional sprays in an effort to raise the solids of grapefruit and early orange varieties.

While discussing the effect of supplemental elements on fruit quality, particularly grapefruit, it is perhaps well to repeat that there is no indication that the use of these elements tends to delay or to hasten to any extent the time at which the fruit will meet the State maturity requirements. This was reported on earlier by Cowart (3) and by Sites (10) and the results of recent years analyses tend to verify these reports.

Source of Nitrogen as Related to Fruit Quality

Questions regarding the source of nitrogen are brought up frequently in connection with any consideration of citrus nutrition and fruit quality. There has been in operation at the Citrus Station since 1944 a nitrogen source experiment in which five different sources of nitrogen; nitrate of soda ($NaNO_3$), ammonium sulfate (NH_4SO_4), organic (castor pomace), urea (Uramon) and ammonium nitrate NH_4NO_3) and combinations of these have been applied to Hamlin oranges. Except for one plot, a basic 4-6-8-4-1-1/2 analysis is applied to the entire block with the source of the nitrogen for the various plots changed in the mixture for each treatment. The trees receive three applications per year at the rate of ten pounds per tree per application. Plots in this block are sampled continuously from September through December. To date no differences of any significance have been found to exist in the internal quality of the fruit produced from any of the treatments. These results are in keeping with those reported by Camp (1) for grapefruit, except that as yet no marked differences in external quality are apparent. It is certainly safe to assume, based on the results of this experiment thus far, that it is not reasonable to expect any quick changes to occur in fruit quality as a result of changes in the source of nitrogen in the fertilizer as long as the ratio and the quantity is kept the same. Although inorganic nitrogen, as the only source of nitrogen, produces acceptable quality fruit so long as all the recognized needed elements are supplied, there is no indication that all inorganic nitrogen is superior to the mixture of inorganic and organic now commonly used. In view of the unsatisfactory past history with regard to the use of all inorganic nitrogen in the fertilizer it would seem wise to at least continue to use mixtures containing at least as much organic nitrogen as is necessary to properly condition the fertilizer. Another point in favor of the use of some organic nitrogen is that it provides some safety against the development of deficiencies which are at present not recognized but which it is reasonable to believe might develop from a completely inorganic program. Nitrate of soda shows a slight advantage over the other forms of inorganic nitrogen which were used.

TABLE I.

FERTILIZER TREATMENT FOR POTASH EXPERIMENTAL PLOTS — BLOCK V.*

Series A

Plot No.	N%	P_2O_5%	K_2O%	MgO%	MnO%	CuO%
1 & 3	3	6	3	0	1	1/2
2 & 4	3	6	10	0	1	1/2
5	3	6	5	0	1	1/2
6	3	6	0	0	1	1/2

Series B

Plot No.	N%	P_2O_5%	K_2O%	MgO%	MnO%	CuO%
1 & 3	3	6	3	3	1	1/2
2 & 4	3	6	10	3	1	1/2
5	3	6	5	3	1	1/2
6	3	6	0	3	1	1/2

* Plots receive 3 applications per year of the above mixtures at the rate of 15 pounds per tree per application. All plots receive a dormant nutritional zinc spray, 3 pounds $ZnSO_4$ per 100 gallons.

Potash Fertilization in Relation to Fruit Quality

The recommendations of the Citrus Station with regard to the use of potash were reviewed by Camp (1) in 1944. At that time responses from the variable potash applications to Block V at the Citrus Station were beginning to be observed in the quality of fruit produced but they had not been continued sufficiently long to make adequate interpretation of the results. The fertilizer treatments applied to this block are summarized in Table I. The postassium treatments are split into two series, A and B. Series A is identical with B except that no magnesium is supplied to any of the plots in this series. Symptoms of potassium deficiency have been more pronounced during the past few years, especially in the series B plot. In view of the fact that potassium in any form has been withheld from the zero potassium plot since 1939, it is interesting to note that potassium deficiency symptoms in these trees have only in the past two or three years developed into more advanced stages. No consistent leaf chlorosis pattern has as yet been observed. The fruit from the deficiency plots is approximately two sizes smaller than from any of the other plots. This fruit is characterized by a thin rind, and is of excellent texture. Another characteristic of the deficient trees is premature dropping of the fruit. This begins in the summer so that much of the crop has been dropped by the time it is ready to be picked. Internal redistribution of potassium is known to occur readily and more or less continuously from the older plant organs to the younger ones. This characteristic undoubtedly accounts for the relatively long period of time it has taken for definite deficiency symtoms to show up in these trees.

Certain changes in the internal characteristics of the fruit as related to the potassium treatments have gradually been taking shape over a period of several years. The results of the analyses for 1946-47 have shown these changes more clearly in some respects than ever before, Table II. The most consistent changes in the juice of the fruit as the potash fertilization increased was an increase in the citric acid content. This increase occurred, however, only when magnesium was adequately supplied. Where magnesium was deficient the acid content of grapefruit juice showed no consistent increase above the 3% potash treatment.

Changes in the soluble solids content of grapefruit show a similar trend as was shown for juice acidity except that the influence of the potassium treatment is slightly less pronounced. In the B Series where magnesium is supplied, there was a fairly sharp rise in solids from the 0% to the 3% treatment and a gradual increase from the 3% to the 10% treatment. Where magnesium was deficient the solids fell off noticeably in the 5% and 10% treatments.

As would be expected, considering the relationship of the potassium applications to the acidity and soluble solids content of the juice, the ratio was much higher from the zero potassium treatment and decreased as the potash applications increased. Fruit from the 0% plot passed the 7.00 to 1 ratio by September 30, whereas fruit from the 10% potash plots did not pass until October 30, a month later. The other treatments were intermediate between these dates.

Differences in the amount of vitamin C in the juice of fruit as related to potassium applications show the same trend that has been discussed for soluble solids. In many cases of fruit analyses there has been observed a very close correlation between the development of soluble solids and the formation of ascorbic acid. The vitamin C increased in the B series plots with the increase of the potash application and showed a sharp increase between the 0% and the 3% treatment. The seasonal averages show the fruit from the 0% plots contained an average of 35.8 mgs. of ascorbic acid per 100 mls. of juice while fruit from the 10% plots contained an average of 41.7 mgs., an increase of 14%.

Table II.

Maturity Analyses of Duncan Grapefruit as Affected by Varying Applications of Potash.

Minus Magnesium (Series A)

Sampling Date	% Citric Acid				% Total Soluble Solids				Ratio			
	0% K_2O	3% K_2O	5% K_2O	10% K_2O	0% K_2O	3% K_2O	5% K_2O	10% K_2O	0% K_2O	3% K_2O	5% K_2O	10% K_2O
Sept. 17	1.06	1.38	1.30	1.40	8.65	8.63	8.05	8.26	8.16	6.27	6.19	5.87
Sept. 30	0.99	1.29	1.25	1.25	8.55	8.58	7.93	8.10	8.68	6.68	6.34	6.50
Oct. 15	1.15	1.20	1.22	1.26	8.65	8.59	8.35	8.35	7.52	7.18	6.87	6.69
Oct. 30	1.09	1.18	1.15	1.16	8.80	9.13	8.40	8.75	8.11	7.74	7.34	7.66
Nov. 12	0.915	1.15	1.14	1.18	9.20	9.47	8.90	8.87	9.89	8.32	7.81	7.56
Seasonal Average	1.04	1.24	1.21	1.25	8.77	8.88	8.33	8.47	8.47	7.24	6.91	6.84

Difference Necessary for Significance between Potash Treatments.

	% Citric Acid	% Total Soluble Solids	Ratio
5% level	.134	.460	1.056
1% level	.181	.620	1.424

Plus Magnesium (Series B)

Sampling Date	% Citric Acid				% Total Soluble Solids				Ratio			
	0% K_2O	3% K_2O	5% K_2O	10% K_2O	0% K_2O	3% K_2O	5% K_2O	10% K_2O	0% K_2O	3% K_2O	5% K_2O	10% K_2O
Sept. 17	1.16	1.28	1.31	1.42	8.05	8.43	8.25	8.66	6.94	6.61	6.30	6.16
Sept. 30	1.05	1.22	1.05	1.34	8.25	8.43	8.38	8.58	7.86	7.93	6.59	6.40
Oct. 15	1.05	1.14	1.15	1.30	8.35	8.60	8.65	8.78	7.99	7.53	7.52	6.73
Oct. 30	0.97	1.12	1.19	1.29	8.80	9.20	8.90	9.40	9.07	8.24	7.48	7.30
Nov. 12	0.845	1.05	1.13	1.19	8.65	9.26	9.20	9.44	10.24	8.89	8.14	7.97
Seasonal Average	1.015	1.16	1.21	1.31	8.42	8.79	8.68	8.96	8.42	7.63	7.21	6.89

Difference necessary for significance between Potash Treatments.

	% Citric Acid	% Total Soluble Solids	Ratio
5% level	.120	.508	1.162
1% level	.162	.684	1.566

Differences between treatments as to the volume of juice extracted were not significant.

The question has been raised in view of these results, whether it would not be advisable to cut down or leave out entirely the potash from the summer fertilizer application, the object being, in the case of grapefruit, to reduce the acidity and produce fruit which would pass legal maturity earlier in the season. There is the further possibility that a lower arsenic application combined with such treatment might be effective and thus reduce the possibility of arsenic toxicity. On the basis of the past performance of these plots the evidence is against this idea working very satisfactorily. Kime (8) showed that potassium leaches out of most Florida citrus soils almost as rapidly as nitrogen. The present potassium applications were started in 1939; yet in spite of this fact there was little evidence of noticeable change in fruit quality before 1943, approximately four years later. It seems doubtful that the omission or the reduction of potash in a single application is going to affect the internal quality of the fruit to any very marked degree. A single year's data on a set of plots started by Dr. B. R. Fudge and carried on in cooperation with the Haines City Exchange shows no indication to date that such changes in potash fertilization would be effective.

Timing of Oil Sprays Affects Fruit Quality

The extent to which the timing of the oil spray will affect internal fruit quality has been discussed on several occasions this year, but since it is especially important for early oranges, a very brief summary of our results is given to complete this discussion. Low solids delayed shipment of the fruit from many Hamlin and Parson Brown groves in 1946 and the same thing is happening again this year. All of this trouble cannot be attributed to improper timing of the oil sprays. Where the timing was poor, the condition was made considerably worse. In general, trends for the early oranges are similar to those reported earlier (13) for Pineapples, but the immediate effect to the grower, may in contrast, be very different. The market is usually best for Hamlins early in the season. Meeting color-added maturity standards then becomes paramount for Hamlins and Parson Browns, whereas this is generally not a serious problem for Pineapples or Valencias; their quality is reduced by improper timing of oil sprays but the fruit can still be shipped. Serious reduction in solids in early oranges, however, may result in the fruit never meeting minimum solids standards or at least not until late in the season. Of particular importance as shown by the results of several seasons are the following points:

(1) The best time to apply single, straight oil sprays to Hamlin oranges is between June 1 and July 15.

(2) Oil sprays applied August 1st and later cause lower solids than those applied during June and July.

(3) All double oil sprays reduce solids more than early single oil sprays.

(4) A proprietary copper-oil applied in early April and followed with a straight oil in June or early July has resulted in higher solids than other double oil sprays.

(5) Straight oil applied June 1 and followed with a second application July 15 is better than any other combination where straight oils as double sprays are used.

(6) Double oil sprays for Hamlin oranges should not be used unless the scale infestation is especially serious. In such cases, a copper-oil applied at melanose time, followed by a straight oil in June or early July is preferable. Where two straight oils are used, the June 1—July 15 combination or a close approximation of these dates has given best results.

(7) Double oil sprays requiring the second oil to be applied during the months of August and September should not be used for early oranges: the reduction in solids is too great.

In general these same statements apply to other orange varieties and to grapefruit. Grapefruit, however, is somewhat less responsive to oil treatments than oranges. Double sprays applied during August and September will result in lower solids fruit, but the effect from single applications of oil sprays during August and September generally does not cause as much reduction in solids for grapefruit as for oranges.

The best way to obtain good fruit quality is to maintain good tree condition. With the possible exception of arsenic for grapefruit, there is no good reliable short-cut to early maturity or high quality fruit. Location, weather conditions, root-stock, and the genetic constitution of the bud wood are all important factors in determining quality but are factors over which the grower has little control. Beyond this, careful attention to the spray program and the selection and careful following of an adequate and suitable fertilizer program which will maintain the grove in good physical condition is the best and most satisfactory way to insure production of high quality fruit.

REFERENCES CITED

1. CAMP, A. F. A Resume of Feeding and Spraying Citrus Trees from a Nutritional Standpoint. *Proc. Fla. State Hort. Soc.* 56:60-79. 1943.
2. COWART, F. F. *Fla. Ag. Exp. Sta. Ann. Rept.* 1940 and 1941.
3. COWART, F. F. The Effect of Magnesium Deficiency in Grapefruit Trees Upon the Composition of the Fruit. *Amer. Soc. Hort. Sci.* 40: 161-164. 1942.
4. COWART, F. F., AND CHAS. R. STEARNS, JR. The Effect of Certain Fertilizer Practices on the Time of Maturity and Composition of Grapefruit and Oranges. *Proc. Fla. State Hort. Soc.* 54: 12-19. 1941.
5. FUDGE, B. R., AND G. B. FEHMERLING. Some Effects of Soils and Fertilizers on Fruit Composition. *Proc. Fla. State Hort. Soc.* 53: 38-46. 1940.
6. HARDING, P. L., J. R. WINSTON AND D. F. FISHER. Seasonal Changes in Florida Oranges. *U.S.D.A. Tech. Bul.* 753, December, 1940.
7. HARDING, P. L., AND D. F. FISHER. Seasonal Changes in Florida Grapefruit. *U.S.D.A. Tech. Bul.* 886, April, 1945.
8. KIME, C. D., JR. Leaching of Potash from Sandy Soils of Florida. *Proc. Fla. State Hort. Soc.* 56. 1943.
9. ROY, WALLACE R., AND GEORGE M. BAHRT. The effect of Zinc, Iron, Manganese and Magnesium Applied to Frenched and Bronzed Orange Groves, on the Vitamin C Content of Oranges. *Proc. Fla. State Hort. Soc.* 53: 34-38. 1940.
10. SITES, J. W. Sourness in Grapefruit in Relation to Seasonal Variations and Nutritional Treatments. *Proc. Fla. State Hort. Soc.* 57. 1944.
11. SKINNER, J. J., G. M. BAHRT AND A. E. HUGHES. Influence of Fertilizers and Soil Amendments on Citrus Trees, Fruit Production and Quality of Fruit. *Proc. Fla. Hort. Soc.* 47: 9-17. 1934.
12. STEARNS, CHAS. R., JR., AND J. W. SITES. The Effect of Magnesium and Other Nutritional Elements Upon the Internal Quality of Grapefruit. *Fla. Ag. Exp. Sta. Ann. Rept.* 207-212. 1943.
13. THOMPSON, W. L., AND J. W. SITES. Relationship of Solids and Ratio to the Timing of Oil Sprays on Citrus. *Proc. Fla. State Hort. Soc.* 1945.
14. WEBBER, H. J. Influence of Environment on Citrus. *Cal. Citrograph* Vol. 23, No. 3: 108 and 126. January, 1938.