# YIELD OF PEEL OIL IN LEMONS AS RELATED TO BUDWOOD AND ROOTSTOCKS

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ABSTRACT

Twenty-one lemon budwood selections on a common rootstock (Florida rough lemon) and seven different rootstocks budded with a common scion (old line 'Bearss') were studied for the yields of peel oil and juice, total acidity and soluble solids. Of the seven budwood selections characterized as the most promising for peel oil yield, 'Bearss', 'Italian' and 'Villafranca' varieties appeared superior. 'Avon' and 'Arizona' varieties were characterized as inferior for peel oil yield. There was no difference in the peel oil yield among the rootstocks or between the nucellar and the old-line budwood selections.

## INTRODUCTION

Commercial lemon production in Florida practically ceased, following the 1894-95 freezes. With the rapid increase in the demand for frozen citrus concentrates the interest in lemon production was revived in the 1950's.

Efforts have been directed toward determining the varieties that are superior in the yield of juice, acid and peel oil. Over 200 lemon selections have been put into commercial plantings in Florida with uniform growing conditions (9). The effects of maturity, variety, climate, fruit size, and rumple of lemons on the peel oil yield have been reported (1,2,4,10). Bitters and Scora (3) noted that rootstocks affect the quality but not the yield of peel oil in 'Valencia' oranges. Hendrickson et al. (6) showed similar results for Florida 'Valencia' oranges and also stated that budwood had a greater influence on the yield of oil than previously anticipated.

The study reported here was undertaken for the purpose of obtaining further information on the influence of certain budwoods and rootstocks on the yield of lemon peel oil. More details of the study are reported in the senior author's Master of Science thesis (5).

## MATERIALS AND METHODS

*Fruit Samples* — The lemon fruit samples were harvested from the cooperative trials of the IFAS Agricultural Research and Education Center at Lake Alfred with the Hodgson Groves, Coca-Cola Co., located at Indiantown, Florida.

Forty budwood selections on Florida rough lemon rootstock were planted in 1956 with five replications per selection. On the basis of those selections producing good yields of fruit, 21 of the 40 selections were used in determining peel oil yield. Eleven were old-line budwood selections and 10 were nucellar budwood selections.

In 1967 the lemon rootstock trial was planted with 30 rootstock selections budded with 'Bearss' old-line and nucellar budwoods. Each selection was replicated five times. Fruit were harvested from 7 of the 30 rootstock selections budded with 'Bearss' old-line budwood.

For the budwood and the rootstock studies, fruit were harvested from 4 trees of each selection. These were chosen on the basis of uniform characteristics with respect to growth, available fruits, and general condition. Samples of 16 fruits from each selection were collected once a month from August through December, 1970. Four fruits were picked per tree, one fruit from each quadrant (N, S, E, W) equidistant between the top and the bottom of the tree.

Five of the high peel oil yielding and three of the low peel oil yielding budwood selections in 1970 were chosen for rechecking peel oil yield in August, 1971.

*Peel oil yield* — The 16-fruit sample was weighed, the longitudinal and equatorial axes of each fruit were measured, the fruits were sprayed with Krylon and air dried. With a two-centimeter diameter cork borer two discs were cut from the unblemished equatorial region of each fruit. Immediately after cutting, the discs were freed with

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a pointed knife and dropped into 300 ml 99% technical isopropanol, for which a tare weight had been obtained. The weight of the 32 discs plus the alcohol was determined and the weight of the discs was obtained by difference. The discs and alcohol were transferred to a stainless steel container and blended with a Waring Blendor at medium speed for three minutes. The blended samples were transferred to one-pint Mason jars, sealed and shaken overnight with a wrist action shaker. The volatile oil was determined by the procedures of Hendrickson et al. (7) and Scott and Veldhuis (11).

The yield of peel oil per unit surface area and yield per ton of fruit were calculated as follows. The surface areas of the fruits were calculated from the measurements of the longitudinal and equatorial fruit axes according to the formula for prolate spheroids (12). The peel oil yield in ml per 100 $cm^2$ of surface areas was calculated on the basis that each disc was 3.30 $cm^2$ and that the bromide-bromate procedure represented 90.7% of the volatile oil present. Pounds of peel oil per ton of fruit were calculated by determining the average volume of oil per unit weight of fruit, extrapolating for the equivalent volume in a ton of fruit and then determining the oil weight using 0.849 as the density of Florida lemon oil.

Table 1. Budwood Study -- Peel oil yields in lemons as related to fruit maturity

| Variety | Selection | Peel Oil Yield (lbs/ton fruit) | | | | | |
|---|---|---|---|---|---|---|---|
| | | August | September | October | November | December | Average |
| | | Old line budwood selections | | | | | |
| Arizona | Alp-28 | -- | 11.659 | 10.385 | 11.832 | 11.416 | 11.323 |
| Avon | Alp-4 | -- | 12.285 | 11.656 | 11.487 | 10.652 | 11.520 |
| Bearss | Alp-11 | 15.451 | 14.825 | 13.963 | 14.451 | 12.394 | 14.217 |
| | E- 403 | 14.840 | 15.114 | 14.772 | 13.930 | 13.737 | 14.478 |
| | E-404 | 15.378 | 14.325 | 13.978 | 14.400 | 13.129 | 14.242 |
| Des-4-Saisons | Alp-21 | 14.602 | 13.681 | 11.964 | 11.931 | 11.568 | 12.749 |
| Harvey | Alp-3 | 12.566 | 12.295 | 11.702 | 11.664 | 12.243 | 12.094 |
| Italian | Alp-26 | 13.204 | 14.124 | 12.904 | 13.548 | 13.717 | 13.499 |
| Moreland | Alp-14 | 13.098 | 13.582 | 12.481 | 11.896 | 11.903 | 12.592 |
| Villafranca | Alp-31 | 15.095 | 14.705 | 13.963 | 13.987 | 12.854 | 14.121 |
| | Alp-38 | -- | 13.169 | 12.691 | 12.757 | 11.599 | 12.554 |
| Average | | 14.280 | 13.610 | 12.769 | 12.898 | 12.292 | |
| | | Nucellar budwood selections | | | | | |
| Bearss | E-421 | -- | 15.746 | 12.947 | 14.091 | 11.895 | 13.670 |
| Lisbon | E-391 | 12.258 | 12.783 | 12.235 | 12.767 | 11.411 | 12.291 |
| | E-398 | 13.682 | 13.143 | 11.344 | 11.537 | 10.050 | 11.951 |
| | E-402 | -- | 12.455 | 11.897 | 13.067 | 11.587 | 12.252 |
| | E-411 | 12.881 | 12.943 | 12.665 | 12.917 | 11.863 | 12.654 |
| | E-418 | 12.805 | 14.574 | 14.501 | 14.347 | 13.736 | 13.987 |
| Nucellars-Misc. | E-408 | 15.005 | 13.597 | 12.589 | 12.385 | 11.697 | 13.055 |
| | E-419 | 13.228 | 11.674 | 11.933 | 11.212 | 10.340 | 11.677 |
| | E-420 | -- | 13.770 | 12.823 | 13.151 | 11.517 | 12.815 |
| Villafranca | E-417 | -- | 13.521 | 13.192 | 13.944 | 12.138 | 13.199 |
| Average | | 13.310 | 13.421 | 12.613 | 12.942 | 11.623 | |

Table 2. Average weight (g) per fruit for each harvest.

| Harvest | Selections | |
|---|---|---|
| | Old Line | Nucellar |
| August | 130.1 | 128.7 |
| September | 148.6 | 151.0 |
| October | 183.2 | 180.7 |
| November | 194.6 | 192.7 |
| December | 209.7 | 219.2 |

## Results and Discussion

With increasing age of the fruit as the monthly harvests progressed from August to December 1970 there was a decrease in the yield of peel oil per ton of fruit (Table 1). The average peel oil yield per ton of fruit for the old line budwood seuections was 14.28 lbs. in August and 12.29 lbs. in December. The average peel oil yield per ton of fruit for the nucellar budwood selections dropped from 13.31 lbs. to 11.62 lbs. during the same period.

Although the yield of oil decreased on a fruit weight basis at each harvest there was a progressive increase in the average weight per fruit (Table 2). The average weight of the old line budwood selections increased from 130.1 g to 209.7 and nucellar budwood selections increased from 128.7 g to 219.2 g. Also the yield of oil per fruit increased the later the fruits were harvested (Table 3). By December the percent increase above the August yield was 38.4 for the old line selections and 48.7 for the nucellar selections. Hendrickson et al. (7) and Hood (8) obtained similar increases in oil yields from oranges the later the harvests were made.

Table 4 gives the average peel oil yield per ton of fruit. The old-line and nucellar budwood selections could be arbitrarily placed into 3 groups according to these yields. These groups are:

Table 3. Increased percent peel oil yield per fruit above the August yield.

| Harvest | Selections | |
|---|---|---|
| | Old Line | Nucellar |
| September | 8.8 | 27.1 |
| October | 25.9 | 33.0 |
| November | 35.2 | 45.6 |
| December | 38.4 | 48.7 |

Table 4. Budwood Study -- Peel oil yield vs. selections.

| Selection | Variety | Av. Peel Oil (lbs/ton fruit) 1970 | Aug. 1971 |
|---|---|---|---|
| E-403 (o)[1] | Bearss | 14.39 a | 20.25 w |
| E-418 (n)[2] | Lisbon | 14.29 ab | 17.50 y |
| E-404 (o) | Bearss | 13.96 abc | 19.94 wx |
| Alp-11 (o) | Bearss | 13.91 abc | |
| Alp-31 (o) | Villafranca | 13.87 abc | 17.59 xy |
| E-421 (n) | Bearss | 13.67 abc | |
| Alp-26 (o) | Italian | 13.57 bc | 16.40 yz |
| E-417 (n) | Villafranca | 13.20 cd | |
| E-420 (n) | Nucellar-misc | 12.82 de | |
| E-411 (n) | Lisbon | 12.60 def | |
| E-408 (n) | Nucellar-misc | 12.57 def | |
| Alp-38 (o) | Villafranca | 12.56 def | |
| Alp-14 (o) | Moreland | 12.45 def | |
| E-391 (n) | Lisbon | 12.30 efg | |
| Alp-21 (o) | Des-4-Saisons | 12.28 efg | |
| E-402 (n) | Lisbon | 12.25 efg | |
| Alp-3 (o) | Harvey | 11.98 fgh | 14.48 z |
| Alp-4 (o) | Avon | 11.52 gh | 14.48 z |
| E-398 (n) | Lisbon | 11.52 gh | |
| Alp-28 (o) | Arizona | 11.33 h | 15.07 z |
| E-419 (n) | Nucellar-misc | 11.29 h | |

Values are the mean among samples analyzed from September to December 1970 and for the month of August 1971.

1 - Old line Budwood selections.

2 - Nucellar Budwood selections.

Means having letters in common are not sifnificantly different at the 95% level as determined by analysis of variance and Duncan's multiple range test.

group 1 — Selections E 403 to Alp. 26
group 2 — Selections E 417 to E 402
group 3 — Selections Alp. 3 to E 419

Group 1 includes the four 'Bearss' selections, the 'Italian' selection and one each of the 'Villafranca' and the 'Lisbon' selections which indicate the most promise for peel oil yield. Group 3 includes the 'Avon', 'Arizona' and 'Harvey' selections and one each of the Nucellar-misc. and 'Lisbon' selections which showed the least promise for peel oil yield. Of the selections studied the 'Bearss' gave the highest yields. Approximately 85-90% of the lemons planted in Florida are the 'Bearss' variety.

The peel oil yields for the eight selections determined in August, 1971 are also presented in Table 4. The oil yield of those selections were higher in 1971 than in 1970, although the order for individual selections is not the same. 'Bearss' selection E-403 gave the highest yield both years. The oil yields for all selections were higher in August, 1971 (Table 4) than in August, 1970 (Table 1). Fruit yields at the Hodgson Groves, Coca-Cola Co. were reportedly lower in 1971 than 1970. Whether oil yields are related to fruit yields or only to seasonal differences should be determined by further studies.

*Rootstock* — No significant differences were found in the yield of peel oil for any of the rootstock selections (Table 5). Bitters and Scora (3) and Hendrickson et al. (6) obtained similar results in studies of the peel oil content of 'Valencia' oranges.

With increasing fruit maturity the changes in oil yields for the rootstock selections were similar to that for the budwood selections. Although the yield of oil per unit surface area increased with fruit maturity, there was a decrease in the oil yield per ton of fruit because the weight of fruit increased at a greater rate than the surface area.

Table 5. Rootstock Study -- Peel oil yields in lemons as related to fruit maturity (Old line budwood selections on seven different rootstocks).

| Rootstock | Peel Oil Yield (lbs/ton fruit) August | September | October | November | December | Average |
|---|---|---|---|---|---|---|
| Cleopatra Mand. | 17.496 | 17.808 | 14.100 | 15.380 | 13.558 | 15.21 |
| Florida Rough Lemon | 15.844 | 16.348 | 14.825 | 13.873 | 13.459 | 14.62 |
| Helseth (Rough Lemon) | 16.793 | 15.497 | 15.101 | 14.202 | 12.895 | 14.42 |
| Macrophylla | — | 15.349 | 14.262 | 14.436 | 12.660 | 14.18 |
| Sour Orange | 18.274 | 16.913 | 14.518 | 14.221 | 12.418 | 14.52 |
| Trifoliata | — | 17.192 | 13.532 | 13.936 | 12.408 | 14.27 |
| Troyer | — | 16.880 | 15.625 | 15.559 | 13.710 | 15.44 |
| Average | 17.101 | 16.569 | 14.566 | 14.515 | 13.015 | |

LITERATURE CITED

1. Bartholomew, E. T. and Sinclair, W. B. 1946. Factors influencing the volatile oil content of the peel of immature and mature oranges. Plant Physiol. 21:319-331.
2. ——————. 1951. The lemon fruit. 143 pp. Univ of Calif., Berkeley.
3. Bitters, W. P. and Scora, R. W. 1970. The influence of citrus rootstocks upon the volatile rind oil content of 'Valencia' oranges. Bot. Gaz. 131(2):105-109.
4. Chace, E. M., Wilson, C. P. and Church, C. G. 1921. The composition of California lemons. U.S. Dept. Agr. Bul. 993:1-18.
5. Drescher, R. W. 1971. Yield of peel oil in lemons as related to budwood and rootstocks. Master of Science Thesis, University of Florida, Gainesville.
6. Hendrickson, R., Kesterson, J. W. and Cohen, M. 1970. The effect of rootstock and budwood selections on the peel oil content of 'Valencia' oranges. Proc. Fla. *State Hort.* Soc. 83:259-262.
7. —————— and Ting, S. V. 1969. Peel oil content of 'Valencia' oranges. Proc. Fla. State Hort. Soc. 81:192-196.
8. Hood, S. C. 1916. Relative oil yield of Florida oranges. Ind. Eng. Chem. 8:709-711.
9. Knorr, L. C. 1958. Finding the best lemon for Florida—A report of progress. I. The growing of lemons in Florida: Historical, varietal, and cultural considerations. Proc. Fla. State Hort. Soc. 71:123-128.
10. ——————, Olsen, R. W. and Kesterson, J. W. 1963. Rumple of lemons—its effects on fresh fruit, lemonade concentrate, and peel oil. Proc. Fla. State Hort. Soc. 76:36-41.
11. Scott, W. C. and Veldhuis, M. K. 1966. Rapid estimation of recoverable oil in citrus juices by bromate titration. Jour. A.O.A.C. 49:628-633.
12. Turrell, F. J. 1946. Tables of surfaces and volumes of spheres and of prolate and oblate spheroids and spheroidal coefficients. Univ. of Calif. Press, Berkeley.

# STORAGE STABILITY OF FOAM-MAT INSTANT ORANGE JUICE AS RELATED TO pH

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ABSTRACT

Flavor stability of foam-mat instant orange juice (IOJ) at 85°F was found to be directly related to pH. At 70°F there was little difference between samples of different pH. Orange juice was adjusted in pH by three methods: 1) Simply neutralizing with KOH, 2) Centrifuging pulp, partially neutralizing serum with calcium hydroxide, centrifuging to remove calcium citrate, and recombining pulp with pH-adjusted serum (these adjusted juice samples were concentrated to about 50° Brix on a falling film evaporator and were subsequently foam-mat dried), and 3) Simply acidifying with citric acid. The resultant IOJ was recombined with acid or sugar to provide pH or Brix/acid of final reconstituted product about the same as the control (pH 3.7). Samples were stored and compared at weekly intervals by triangular taste tests for significant detectable differences between samples stored at 85 or 70°F and controls maintained at -5°F. Samples developed no change up to 26 weeks at 70°F. Storage stability at 85°F lessened as pH increased. At pH about 4, 5 and 6 changes occurred at 2-4 weeks. The control, at about pH 3.7, developed a difference at 5 weeks, and at pH 3.3 samples were stable for 13 weeks. Thus, slightly increased acidity appeared helpful in flavor stabilization. This implies that more acid juices might have greater stability and may partially account for instant grapefruit juice showing better storage stability than IOJ.

"References to specific commercial products do not constitute endorsement. A laboratory of the Southeastern Marketing and Nutrition Research Division. Cooperative research with the State of Florida Department of Citrus."

INTRODUCTION

Instant orange juice (IOJ) is a new citrus product which is receiving ever increasing industrial and consumer interest. Aside from the convenience of a naturally flavorful and nutritious product in easy to prepare form, and advantages in reduced shipping cost due to removal of moisture, additional advantages of such dehydrated products usually are found in the lack of need for refrigeration in storage and the stability of the product. However, difficulties have been encountered in storage stability of instant orange juice prepared by foam-mat drying. Although both instant orange and grapefruit juice were found stable at 70°F for 40 weeks or longer without significant detectable flavor changes, differences were found between storage stability of instant grapefruit juice and IOJ at 85°F (2). While instant grapefruit juice remained stable for 12 weeks or more at 85°F, instant orange juice was found to develop significant detectable flavor changes in 4-6 weeks at 85°F.

Chemical analytical studies on stored instant orange juice indicated the principal cause of storage changes was nonenzymic browning, principally due to reactions between sucrose, fructose, glucose, and ascorbic acid in the natural acidic medium of