Proc. Fla. State Hort. Soc. 94:363-367. 1981.

EXPLOSION PUFFED RABBITEYE BLUEBERRY STORABILITY AND QUALITY EVALUATION

ELIAS D. DEKAZOS[1]
USDA, Agricultural Research Service,
Richard B. Russell Agricultural Research Center,
College Station Road,
P.O. Box 5677, Athens, GA 30613

Additional index words. Explosion puffing process, nutrient status, mineral composition, elemental analysis, plasma emission spectroscopy, gas-liquid chromatography (GLC) analysis, volatile components of rabbiteye blueberries, *Vaccinium ashei.*

Abstract. **Rabbiteye blueberries** (Vaccinium ashei **Reade) cultivars 'T-19', 'Tifblue' and 'Woodard' were successfully explosion puffed. Studies were made on the effects of cultivars, storage time, and temperature differences on the quality of explosion puffed berries. Explosion puffed berry quality was rated by color and degree of rehydration. For each quality attribute, differences in berries were due to effects of storage time and not to storage temperature. Puffed berries when compared to fresh berries decreased in fruit coloration and increased in redness. In further studies of quality attributes, the concentration of 19 mineral elements considered essential for human nutrition were determined. Potassium had the highest concentration of all the mineral elements for fresh and puffed berries. Explosion puffed blueberries indicate that they are a fair source of K, Fe and Mn. There are seven major volatiles produced in the fresh berries which are also produced in the explosion puffed fruit. The high quality of the new product, explosion puffed blueberries, is evidenced by the preservation of aroma and the other quality attributes studied.**

The rabbiteye blueberry (*Vaccinnium ashei* Reade) is native to the southeastern United States and is one of the 3 types of blueberries that are grown commercially. The other two types are lowbush (*Vaccinium angustifolium* Ait.) and highbush (*Vaccinium corymbosum* L.). Several cultivars of rabbiteye blueberry that were developed at the Coastal Plain Experiment Station are recommended for planting in Georgia (1).

The United States leads the world in blueberry cultivation. In Georgia alone the rabbiteye is to provide a multi-million-dollar cash crop. Complete statistics of blueberry production in the Southeastern States are not available. However, this is a crop with great potential as the rabbiteye blueberry, a southern species, requires little care and has a great immunity to disease and insects. It seems that the rabbiteye blueberry industry has great potential for expansion in the next few decades. All available technology should be supplied to this new industry.

Explosion puffing is the most unusual dehydrating process to date and has been applied to apples and blueberries (2, 5, 6, 7). This process involves tiny punctures on the skin of the blueberry by an explosion process similar to blowing blueberries out of a cannon and preserves fresh berries for decades. The batch gun explosion puffing and the continuous explosion puffing (where the heating and puffing functions are separable) were two systems used for explosion puffing in this study. Separating these two major functions in a continuous system results in better process control, improved production capacity and product quality, reproducibility of product, and reduced labor costs (9). The continuous explosion puffing system has been successfully applied to potatoes, carrots and apples (16, 17, 18). The explosion puffing process was first reported in 1961 (8, 11). Explosion puffing should have substantial application in fruit processing in the future. The explosion puffing process was adapted and optimum operating conditions for continuous explosion puffing system were established for rabbiteye blueberries (15).

In order to enhance the economic value of the crop, explosion puffing was applied to rabbiteye blueberries. This is a new marketing boost for the rabbiteye blueberries. The European market is now being explored for accepting this new product since the fresh and frozen product has gained acceptance among European consumers and processors.

With the expansion of this product, it becomes increasingly important to develop information on the quality and nutritional content of this new product. Many minerals are essential for normal metabolic functions and are required components in a balanced diet (14, 19). Some nutritional research on fresh lowbush (10), highbush (20) and rabbiteye (3) blueberries has been done.

This investigation was undertaken to 1. study the effects of cultivar, storage time and temperature on the quality of explosion puffed berries, 2. determine the contents of 19 elements essential for human nutrition in explosion puffed blueberries and 3. examine the qualitative analysis of blueberry volatiles and determine the extent to which the explosion puffing method affects them.

Materials and Methods

Quality evaluation of explosion puffed berries

The 'Tifblue', 'T-19' and 'Woodard' rabbiteye blueberries were harvested at Alma, Georgia, cleaned by a pneumatic winnower, transported in an air conditioned automobile to the laboratory in Athens, Georgia, where they were held at 4.4°C overnight. The berries were washed, strained, cleaned and dried, then examined for various quality parameters and the data recorded. Blueberry samples were transported by air-freight to the Eastern Regional Research Center (ERRC) in Philadelphia, Pennsylvania, for explosion puffing. The method for preparing dehydrated explosion puffed commodities was developed by the ERRC. The essential steps in the process for explosion puffed blueberries, whether batch or continuous, are depicted in the flowsheet in Figure 1.

Blueberries were air-dried in the Sargent continuous belt drier or the National tray drier. After initial drying (82°-88°C), the berries were mixed and equilibrated. They were further dried to a moisture between 17 and 19% (wet basis) then puffed in continuous explosion puffing system (CEPS) at 20 psig puff pressure, at 1 minute retention, with the internal temperature at 160°-177°C; however, the 1975 'T-19' berries were puffed in a batch gun at 30 psig discharge pressure and 132°C superheated steam temperature. By exposure to pre-determined pressure values, the berries were quickly heated and their remaining water superheated relative to atmospheric pressure. When the blueberries were

[1]I thank Dr. Robert Horvat, Research Chemist, for the gas chromatography analysis. Mention of a trade name does not constitute a guarantee or warranty of the product by the U.S. Dept. of Agriculture and does not imply its approval to the exclusion of other products that may also be suitable.

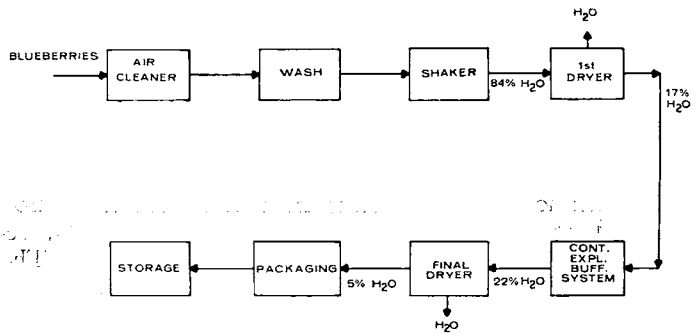

Fig. 1. Flowsheet depicting the essential steps in the process for explosion-puffed blueberries, whether batch gun or continuous system.

suddenly discharged to the atmosphere, the rapid pressure drop caused some of the water within the berries to flash into water vapor. The flashing water vapor from within each berry created a porous structure that permitted much faster dehydration and much more rapid rehydration of the dried berries. The berry structure was retained after drying. The final drying was accomplished at 66°C with final moisture being less than 5% (15).

These explosion puffed berries were packed in cans and sealed at ERRC and transported to Russell Research Center (RRC) in Athens, Georgia, for further evaluation. Canned berries were stored at 4.4°C (40°F) and 22.2°C (72°F) to evaluate quality by physical and organoleptic means. Explosion puffed berries were rated by color (4) and degree of rehydration. The absorbance of rehydration water was read at 520 and 420 nm. The browning index 520 nm/420 nm was calculated. Experiments were also conducted to determine the effects of temperature and storage time on the quality of the explosion puffed berries.

Blueberry mineral determination

For mineral determination, the explosion puffed 'Tifblue' blueberries, the primary commercial cultivar, were further dried in a vacuum oven at 60°C for 24 hr, then placed in a vacuum desiccator, ground in a Wiley mill to pass a 40-mesh screen in a room of temperature 21°C and 25% relative humidity, and returned to the desiccator. Minerals were determined by plasma emission spectroscopy (12). A 0.5 g sample of explosion puffed, ground tissue was dry ashed in a muffle furnace at 500°C for 4 hr and then cooled. Five-ml of concentrated nitric acid was added to the sample. Using a glass stirring rod, the carboneous ash was broken up and placed on a hot plate to dry. The samples were further ashed at 500°C for an additional 4 hr. After cooling, the ash was taken up in 10 ml of 20% HNO_3 containing 10 ppm Mo as internal standard. The ash solution was analyzed for P, K, Ca, Mg. Fe, Mn, Cu, Zn, Na, Al, Si, Co, Cr, Ni, Pb, Cd, Sr and Ba by using a direct reading inductively coupled plasma emission spectrometer (Jarrell-Ash 0.75 m, Model 750, Fisher Scientific Co.). All mineral data in this study were converted to mg/100 g fresh berry weight (3).

Blueberry concentrate and gas chromatography analysis

Fresh 'Tifblue' and explosion puffed blueberries were used for the isolation of volatiles. Two-hundred gram samples of fresh and explosion puffed berries were blended with 200 ml distilled water in a Waring Blendor. The blended sample was then placed in a 3-liter round-bottomed flash with 425 ml distilled water added. The flask was connected to a Likens and Nickerson-type steam distillation continuous pentane extraction apparatus (13). The pentane and the berries were boiled for 5 hr. After the apparatus had cooled, the flask containing the pentane was removed. The pentane extract was maintained at 40°C and was concentrated to 0.1 ml by blowing a gentle stream of high purity nitrogen on its surface.

Separation of the mixture (approximately 1 μl volume concentrate) was accomplished by gas-liquid chromatography in a Perkin-Elmer Model 900 gas chromatograph using 500 ft x 0.02 in i.d. stainless steel open tubular column coated with Supelco 2100. Both injector and detector were maintained at 22°C. Helium pressure was 16 psi. The column was kept at 70°C for 6 min and then programmed at 2° per min to 210°C.

Results and Discussion

Puffed blueberry quality

Experiments were conducted over a six-year period: 1975: 'T-19' dehydrated by explosion puffing gun, stored for 51 months; 1976; 'T-19' and 'Tifblue' dehydrated by continuous explosion puffing system (CEPS), stored for 39 months; 1977: 'Tifblue dehydrated by CEPS, stored for 27 months: 1978: 'Tifblue', 'Woodard' both dehydrated by CEPS, stored for 15 months; 1979: 'T-19' and 'Tifblue' dehydrated by CEPS, stored for 4 months; and 1981; 'Tifblue' dehydrated by CEPS, stored for 1 month.

Explosion puffing of rabbiteye blueberries conducted during the five successive seasons, 1975-1979 crops, and 1981, covered various climatic conditions: a wet 1976, drought in 1977 and 1981, and a dry growing season with a normal harvest in 1978. The cultivars used were 'T-19', 'Tifblue' and 'Woodard'. 'Tifblue' and 'Woodard' are the most important commercial rabbiteye blueberries in the South. All berries processed well: 'T-19' and 'Tifblue' were the best as they were firmer than 'Woodard' (3).

The "L" values which measure lightness or darkness were considerably lower for the explosion puffed than fresh berries indicating that explosion puffed berries were darker than the fresh fruit (Table 1). Furthermore, the negative "b" values which measure blueness decreased for puffed berries compared to fresh berries. An increase in all the "a" values, which measure redness, was recorded for the explosion puffed berries (Table 1). The rehydrated puffed berries compared to fresh followed the same pattern for the "L", "a" and "b" values as for the explosion puffed (Table 1).

A comparison between rehydrated and explosion puffed berries shows that the "L" and "b" values are lower and the "a" values higher for the rehydrated puffed berries. The berries sealed in cans and stored at 4.4°C did not retain more color than those stored at 22.2°C which means that the storage of berries at lower temperatures does not increase the retention of color. This processing method preserves the color of berries equally well, if not better, at 22.2°C storage than at 4.4°C. Slight differences in berry color were due to the effects of time and not the storage temperature. The higher initial "b" values of the fresh berries, the greater the preserved blueness in the processed and stored fruit with less loss of anthocyanins in the rehydration water. The rehydration values, with the lowest for 'Woodard', differ among the various cultivars (Table 1). The rehydration water of the explosion puffed 'Tifblue' berries had the highest browning index (least browning) independent of storage duration. Browning was highest (lowest browning index) for the 1975 berries which were batch gun explosion puffed.

The drained weight of the explosion puffed berries reached 50% of the fresh weight. This figure is somewhat similar to that reported for dried lowbush blueberries (10).

To determine storage effects on blueberry quality,

Table 1. Effects of cultivar, storage time and temperature on quality of explosion puffed rabbiteye blueberries: rated by color and degree of rehydration.

Year	Cultivar & storage temperature (°F)	Storage duration (months)	Hunter Color Values: Explosion puffed berries L	a	b	b/a	Rehydrated puffed berries L	a	b	b/a	Rehydration values (gr)	Color of Rehydration Water: Absorbance (520nm)	(420nm)	Browning index (520/420)
1975	T-19	51												
	4.4°C		17.25	2.75	−0.60	−0.22	11.40	3.70	−0.53	−0.16	45.78	.771	.940	.822
	22.2°C		17.95	2.10	−0.73	−0.35	10.53	4.13	−0.47	−0.11	44.92	.940	1.044	.900
1976	T-19	39												
	4.4°C		16.35	2.93	−0.85	−0.30	11.40	5.88	−0.93	−0.16	42.53			
	22.2°C		16.68	2.33	−0.93	−0.40	10.70	5.27	−0.63	−0.12	43.70	1.896	1.564	1.209
	Tifblue	39												
	4.4°C		15.88	2.10	−1.08	−0.52	9.50	4.60	−1.23	−0.28	46.58			
	22.2°C		21.50	2.40	−1.18	−0.49	9.50	5.03	−0.87	−0.17	44.92	2.660	1.971	1.348
1977	Tifblue	27												
	4.4°C		16.70	2.43	−1.03	−0.42	10.45	5.63	−0.63	−0.12	47.67			
	22.2°C		17.65	2.00	−1.18	−0.60	10.87	4.20	−0.77	−0.19	46.87	1.917	1.363	1.398
1978	Tifblue Hand-harvested	15												
	4.4°C		15.33	1.95	−0.95	−0.50	10.63	3.85	−0.85	−0.22	38.14			
	22.2°C		16.48	1.33	−1.30	−0.99	10.37	4.70	−0.90	−0.20	37.16	.917	.868	1.056
	Mechanically Harvested													
	4.4°C		15.10	1.40	−1.05	−0.76	9.70	2.93	−0.88	−0.30	35.33			
	22.2°C		15.63	1.20	−1.25	−1.04	10.13	3.03	−0.83	−0.28	34.42	.999	1.005	.993
	Woodard	15												
	4.4°C		16.78	0.98	−1.60	−1.66	9.58	2.63	−0.95	−0.39	35.10			
	22.2°C		17.18	0.78	−1.63	−2.13	10.37	2.00	−0.83	−0.42	33.13	.917	1.013	.905
1979	T-19	4												
	4.4°C		15.28	2.13	−1.03	−0.49	10.58	4.70	−0.68	−0.15	40.70			
	22.2°C		14.93	1.70	−1.05	−0.62	10.67	4.27	−0.53	−0.13	38.38	1.280	1.297	.987
	Tifblue	4												
	4.4°C		15.15	1.53	−1.13	−0.74	10.48	3.13	−0.93	−0.30	35.58			
	22.2°C		14.78	1.20	−1.23	−1.03	9.67	3.97	−0.83	−0.21	36.60	1.588	1.500	1.058

Control Fresh Berries	Range of Hunter Color Values (1975-1979) L	a	b	b/a
T-19	20.85-20.95	0.35-0.38	(−2.89)-(−2.92)	(−7.61)-(−8.25)
Tifblue	20.22-21.14	0.38-0.58	(−3.15)-(−3.55)	(−6.91)-(−8.37)
Woodard	19.22-19.31	0.39-0.40	(−3.20)-(−3.28)	(−8.00)-(−8.20)

samples of 'Tifblue' (1976-1979) at 4.4°C and 22.2°C and 'T-19' (1979) at 22.2°C were tested in an incomplete randomized block: 5 samples, 4 replications on each sample. A sample of commercially canned berries was included for comparison. Explosion puffed berries were significantly firmer than commercially canned berries. 'Tifblue', 1977 berries stored at 4.4°C were significantly less firm than 'Tifblue', 1979 berries stored at 22.2°C. Time of storage apparently had more influence on texture quality than storage temperature.

The new product, explosion puffed blueberries, a first for rabbiteye blueberries, keep well at ambient temperature, reduce product weight in transit and cut down on spoilage, and rehydrate quickly which is an improvement over the conventionally dried berries.

Mineral analysis of explosion puffed berries

Nineteen mineral elements of 'Tifblue' explosion puffed berries of the 1976-1979 and 1981 crops were identified and quantitated (Table 2). Phosphorus, K, Ca, and Mg were present in appreciable amounts; whereas, Fe, Mn, B, Cu, Zn, Na, Al, Si, Co, Cr, Ni, Pb, Cd, Sr and Ba were present in trace amounts. Potassium showed the highest mineral concentration, averaging 84.3 mg/100 g fresh weight for the above tested years, following the pattern set by the fresh crop.

A direct comparison, of the 1976 explosion puffed berries, analyzed in 1980, with the fresh berries of the 1976 crop shows mineral losses to be 33% for P, 2% for K, 10% for Na, etc. with variation from element to element showing small nutrient losses during processing. The 1981 analysis of the 1976 explosion puffed berries compared to the previous year analysis (1980) showed minimal or no loss in nutrient content except for Na, Al and Si.

Also listed in Table 2 are values for explosion puffed berries for 1977, 1978, 1979 and 1981, all analyzed in 1981. An indirect comparison of these values with the ones of the 1976 fresh berries showed approximately 9-29% loss for P, with small or no loss for the other elements.

The composition of explosion puffed rabbiteye blueberries, like the fresh fruit, indicates that they are a fair source of K, Fe and Mn compared with the Recommended Daily Dietary Allowance (RDA) (3).

Chromatogram comparison of fresh and explosion puffed blueberries

Aroma of fruits is the key factor for assessing their quality as well as their identity. Fruits of prime quality always possess their characteristic aroma in full strength, besides the other quality attributes.

The volatile components of rabbiteye blueberry concentrate were separated by gas chromatography. The gas

Table 2. Elemental concentration of rabbiteye blueberry fruit and dried explosion-puffed berries (mg/100 g fresh berries).

Cultivar and product	Crop year	Year of analysis	P	K	Ca	Mg	Fe	Mn	B	Cu-	Zn	Na	Al	Si	Co	Cr	Ni	Pb	Cd	Sr	Ba
Tifblue																					
Fresh[z]	1976	1976	8.5	78.2	5.1	5.1	0.20	0.22	—	0.19	0.09	0.85	0.56	0.48	0.01	0.04	—	0.15	0.01	—	—
Explosion-puffed berries	1976	1980	5.72	76.59	5.49	5.45	0.25	0.17	—	0.14	0.10	0.76	0.52	0.50	0.008	0.03	—	0.17	0.008	—	—
Explosion-puffed berries	1976	1981	5.66	76.50	5.46	5.46	0.23	0.19	0.04	0.11	0.11	0.64	0.24	0.27	0.005	0.02	0.004	0.13	0.005	0.005	0.013
Explosion-puffed berries	1977	1981	6.0	89.02	7.98	9.99	0.18	0.12	0.03	0.06	0.08	0.45	0.29	0.39	0.001	0.002	0.002	0.21	0.001	0.007	0.02
Explosion-puffed berries	1978	1981	6.88	85.14	4.83	8.52	0.16	0.17	0.04	0.05	0.11	0.37	0.21	0.43	0.005	0.001	0.001	0.02	0.003	0.004	0.01
Explosion-puffed berries	1979	1981	6.24	86.94	5.45	7.55	0.21	0.14	0.04	0.06	0.34	0.38	0.20	0.23	0.001	0.001	—	0.03	0.001	0.005	0.01
Explosion-puffed berries	1981	1981	7.69	91.49	6.69	9.34	0.39	0.10	0.06	0.07	0.10	0.37	0.28	0.27	0.001	0.002	—	0.02	0.001	0.006	0.02

[z]Dekazos (1978)

chromatographic curve of fresh and explosion puffed 'Tifblue' rabbiteye blueberries are given in Fig. 2.

The retention times of the volatile compounds of the blueberry concentrates were compared with the retention times of known compounds. Preliminary identification of the compounds is given in Fig. 2. The six volatiles identified were ethyl acetate, ethyl isovalerate, hexanal, trans-2-hexanal, 2-ethyl-hexanol and nerol. Cooperative research is in progress for positive identification of all the compounds and for their recombination to demonstrate the importance of specific ones to the characteristic rabbiteye blueberry flavor.

This report establishes the fact that there are seven major volatiles produced in the fresh berries which are also produced in the explosion puffed berries.

The evidence of preservation of aroma along with the other quality attributes discussed earlier attest to the high quality of the new product.

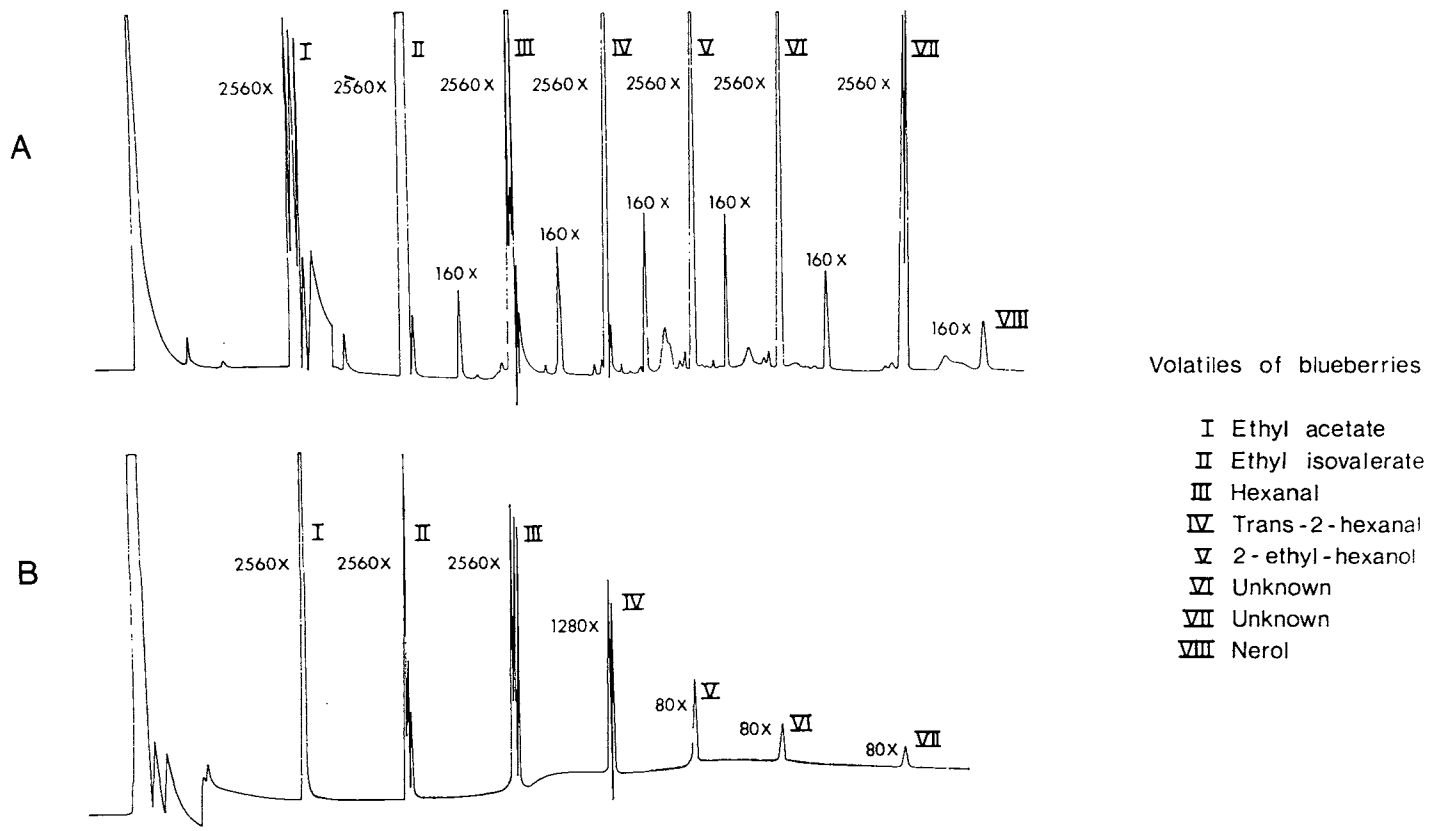

Fig. 2. Volatiles produced by a sample of A. fresh and B. explosion puffed 'Tifblue' rabbiteye blueberries. 1981 crop.

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Proc. Fla. Hort. Soc. 94:367-369. 1981.

CGA-15281 INDUCED ABSCISSION ZONE FORMATION IN PEACH FRUIT[1]

C. E. Arnold
University of Florida, IFAS, Agricultural Research Center, Monticello, FL 32344

L. C. Anderson and G. L. Thomas
Florida State University, Dept. of Biological Sciences, Tallahassee, FL 32306

J. H. Aldrich
University of Florida, IFAS, Agricultural Research Center, Monticello, FL 32344

Additional index words. chemical thinner, ethylene release, *Prunus persica.*

Abstract. **Initial stages of chemically-induced fruit abscission from application of CGA-15281 in peach,** Prunus persica **(L.) Batsch, are described. Salient features that differ from modes of separation in other stone fruits include simultaneous production of 2 abscission zones along the fruit pedicel and the centripetal development from cortex to pith of the separation layers.**

Fruit thinning compounds are normally applied to the fruit surface where the release of ethylene as a decomposition product within the plant tissue (7) either directly or indirectly elicits the formation of an abscission zone. High ethylene concentrations in the abscission zone at the base of the pedicel are believed to stimulate rapid growth of proximal cells and the formation of polysaccharide hydrolyzing enzymes (4). This model suggests that ethylene promotes fruit abscission by stimulating both unequal cell growth and digestion of the middle lamella in the abscission zone.

CGA-15281, an ethylene releasing compound, has been under investigation as a peach fruit abscission agent for several years. These studies, though not conclusive, have been instrumental in determining the range of useful concentrations (1), the effectiveness at various stages of fruit maturation (2), the response to different methods of application (3), and other general horticultural information.

This study was undertaken to monitor the development of abscission zone formation in peach following application of CGA-15281 to the entire tree.

Materials and Methods

Treatments of aqueous solutions of 600 or 720 ppm CGA-15281 were applied to 6-year-old 'Harvester' peach trees at the end of the "shuck off" stage (abscission of the floral cup) of fruit development (ovule length 4-6 mm) on April 5, 1980 and were compared to suitable controls. An airblast speed sprayer delivered 2 gal/tree at 100 psi through 4 nozzles.

Samples included adjacent stem, pedicel, and proximal portion of the fruit. Collections were from treated and untreated trees before and at various intervals after application. The samples were fixed, dehydrated, imbedded in paraplast, sectioned at 12 μ, mounted, and stained in safrauin and fast green.

Results and Discussion

Abscission zone development was not detected in pedicels

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