Postharvest Physiology of Strawberry Fruits Treated With Sodium Dehydroacetate[1]

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Abstract. Sodium dehydroacetate (NaDHA) was most effective in extending the shelf life of fruits of strawberry cultivars that have the poorest holding capacity. Decreased respiration of treated fruits is attributed to the fungicidal property of NaDHA or inhibitory effect of the chemical on a respiratory enzyme of the fruit. A 0.5% NaDHA solution retarded ripening.

Various types of fungicides have been evaluated to reduce decay and rot of harvested strawberry fruit (3, 5, 7, 8). Many of these chemicals were effective as a fungicide; however, the wettable powder fungicides left an undesirable visual residue on the fruit. The Na salt of dehydroacetic acid was reported to be an effective fungicide (5, 6, 7, 9) and was appealing due to its solubility in water, lack of visual residue and relatively high (65 ppm) residue tolerance on strawberries. A 0.5% solution of NaDHA (sodium dehydroacetate) was found to be effective in controlling storage decay caused by species of *Rhizopus, Alternaria* and *Botrytis*. Sodium dehydroacetate has been reported to be effective in extending the shelf life of cubed squash (2) and reducing discoloration of snap beans (4). This compound is also used in pharmaceutical materials to prevent decomposition. Since NaDHA exhibited potential as an effective fungicide, a study was made to determine the effect of this compound on the shelf life, respiration rate and rate of ripening of the harvested strawberry fruits.

Materials and Methods

Fruits of 'Midway', 'Surecrop', 'Sunrise' and 'Catskill' cultivars of strawberry (*Fragaria ananassa* Duch.) were used. The fruits were harvested in the early pink stage of ripeness and were either dipped in or sprayed with various concentrations of NaDHA for 60 seconds. Two types of controls were followed: one set was kept dry and the other set was dipped in water for 60 seconds. The fruits were enclosed in a jar at 20°C and humidified air was metered over the sample. After 4 days of the holding period, the fruits were evaluated for their marketability and for their ripeness. Marketability was based on visual quality using guidelines at the level of retail market. Respiration rate of whole fruit was measured daily by either the Claypool and Keefer method (1) or with a MSA infrared CO_2 analyzer. Each sample contained 25 fruits and the study was repeated 6 times over a 2-year period.

Oxygen uptake of 3 x 8 mm circular tissue slices from the surface and internal pulp section of a light pink fruit of 'Surecrop' was measured separately with the GME differential respirometer. The skin of the surface tissue was removed. One gm. of the tissue slices was washed in a 0.2 M phosphate buffer (pH 7.4) and placed in Warburg flasks containing phosphate buffer. Preliminary studies indicated that maximum effectiveness with NaDHA was obtained at pH 7.4. Sodium dehydroacetate at various concentrations was placed in the side arm of the Warburg flask. After initial O_2 uptake readings were made for 20 minutes, the NaDHA was dipped into the main well containing the strawberry tissues. The readings were continued at 10-minute intervals for an additional 60 minutes.

Results and Discussion

The cultivars responded differently in their marketability to the NaDHA treatment. The percentage of marketable fruit of all cultivars except 'Catskill' was considerably lower when the fruit was dipped in water as compared to those that were held dry (Table 1). Treatment of the 'Catskill' sample with 0.25 and 0.5% solution resulted in a 2- and 3-fold increase, respectively, in marketable fruits. 'Surecrop' responded only slightly to a 0.25% solution, whereas a 2-fold increase in marketable fruit was noted with the treatment of 0.5% solution. Marketability of 'Sunrise' was drastically reduced when dipped in water, but treatment with 0.25% NaDHA prevented this deleterious condition. Treatment of 'Sunrise' sample with 0.5% NaDHA resulted in about a 1.5-fold increase in marketable fruits when compared with the dry sample. 'Midway' was also affected very seriously when dipped in water and the NaDHA treatment of either 0.25 or 0.5% concentration was of no value when compared with the dry sample. In the preliminary study, a slight benefit of 'Midway' was noted with the NaDHA treatment.

Sodium dehydroacetate treatment appears to be more effective with cultivars that have the poorest holding capacity. Among the cultivars studied 'Catskill' had a very low percentage of marketable fruits when held dry. Next in sequence was 'Surecrop' followed by 'Sunrise'. The effectiveness of NaDHA possibly may be related to physical and chemical properties of the various cultivars.

The respiration rate of all the fruit tissues increased with holding and was affected by NaDHA. The degree of response to the treatment differed among cultivars, however, since the pattern was the same, the average relative respiration rate of all cultivars for each treatment is plotted in Fig. 1 using the first day rate as the base. The slope of increase of water-dipped fruit was slightly greater than those held dry. Sodium dehydroacetate had an inhibitory effect on the degree of increase. An exception to this was noted with the 'Midway' cultivar, in which the respiration rate of the samples treated with 0.25% concentration did not differ greatly from that of samples held dry. The inhibitory effect of NaDHA was greater at the higher concentration. The final rate of these samples had increased to about 80% of that of the control.

Table 1. Percentage of marketable fruits of strawberry cultivars after 3 days at 20°C following treatment.

	Catskill	Surecrop	Sunrise	Midway	Average
Dry	17	26	39	66	37 b[1]
Water	21	23	14	38	24a
NaDHA 0.25%	40	32	57	39	49 bc
NaDHA 0.50%	55	50	62	71	59 c

[1]Averages with common letters are not significantly different at the 5% level as determined by Duncan's Multiple Range Test.

[1]Received for publication June 10, 1970. Published with the approval of the Director of the West Virginia Agricultural Experiment Station as Scientific Paper No. 1122. This study is part of the Northeastern Regional Research Project NEM-33 and was partly supported by the Regional Research Fund.

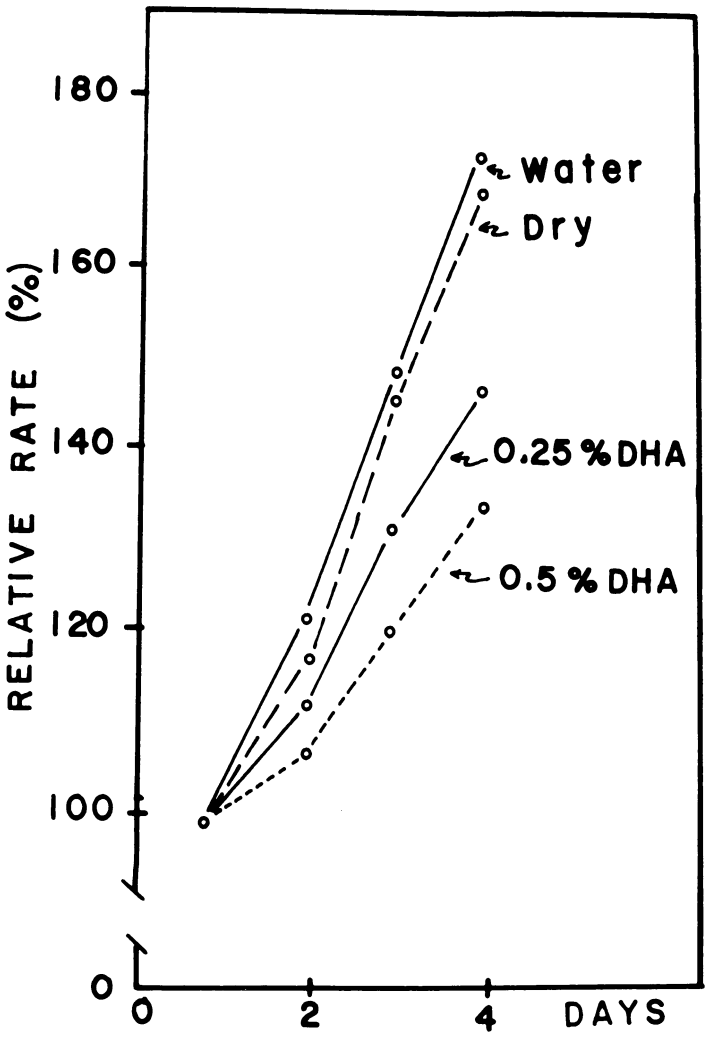

Fig. 1. Relative respiration rates of whole strawberry fruits at 20°C. Fruits treated with water or NaDHA.

It was of interest to determine if NaDHA had a direct or indirect inhibitory effect on the respiration rate. The NaDHA could have a direct effect by inhibiting an enzyme of the fruit tissue that catalyzes one or more of the respiratory reactions. An indirect affect could result from the fungicidal property of NaDHA. As fungal growth was controlled, the stimulated respiration that is generally observed with invasion would not occur. This would result in a lower respiration rate by the treated sample than the nontreated sample. This question was studied by observing the respiration rate of tissue slices exposed to NaDHA.

The rate of O_2 uptake of the tissue slices decreased with time (Fig. 2). Since both the surface and inner pulp tissues responded similarly to NaDHA, only the results of the surface tissue are presented. The respiration rate of the tissue slices treated only with water (control) decreased from 1.15 to .77 ul O_2/g-min. during the 20 to 80 minute period. The degree of reduction was greater with NaDHA-treated tissue. A 0.5% treatment resulted in a decrease from 1.10 to .42 ul O_2/g-min. The inhibitory effect of NaDHA was apparent immediately with the inhibition being greater with increased concentrations up to 0.5%. Beyond 0.5% concentrations, the samples did not differ in the degree of inhibition. If NaDHA was inhibiting a specific enzyme these results indicate that it is not competing with an *in vivo* substrate for the enzyme. On the other hand, since a 0.5% solution exceeded 10^{-3} M concentration of NaDHA, toxicity effects may have begun to play a role at this level. Perhaps a 0.5% solution was sufficiently toxic to cause maximum inhibition. Nevertheless, the results indicate that NaDHA does inhibit the respiration rate directly.

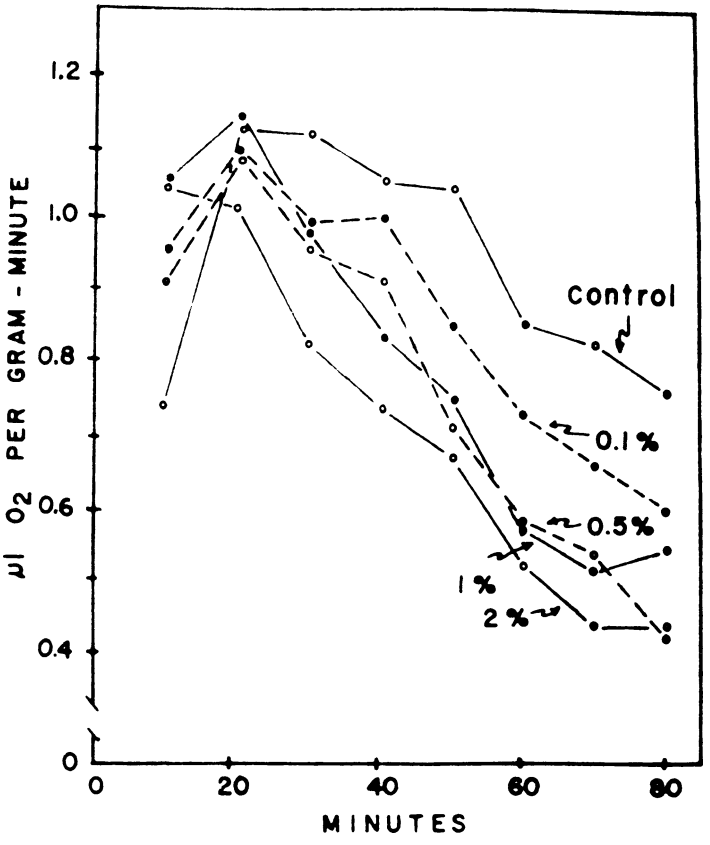

Fig. 2. Respiration rate of tissue slices of 'Surecrop' strawberry fruits at 20°C. NaDHA of different concentrations was added 20 minutes after initiation of measurement.

The NaDHA solution affected the rate of ripening of the strawberry fruits. This was noticeable particularly with 'Sunrise' and 'Surecrop'. After 4 days at 20°C the fruits of the dry sample and those dipped in water were in a ripe to overripe state. Fruits treated with 0.25% solution had also ripened but not to the extent of those held either dry or dipped in water. A more definite retardation in ripening was noted with samples dipped in 0.5% NaDHA solution. These fruits did ripen with extended holding. The sheen of the fruit disappeared when the fruits were dipped in water or NaDHA solution. Spraying with a fine mist of NaDHA solution retained the sheen on the fruit without affecting the inhibitory influence of the chemical.

It appears as though NaDHA extends the shelf life of strawberry fruits by 2 different mechanisms. As reported by others (3, 5) NaDHA probably inhibited germination of fungus spores and alleviated infection. At the same time, NaDHA may have inhibited the activity of an enzyme participating in the respiratory pathway. As the respiration rate was reduced, other related metabolic processes including ripening were retarded. This would cause the fruit to remain in various stages of ripening for a longer period and subsequently extend the duration of marketability.

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The Effect of Light Intensity on the Soluble Carbohydrate Level and Macronutrient Composition of *Ilex opaca* Ait.[1]

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Abstract. Soluble leaf carbohydrates, macronutrient elements and growth responses to 3 levels of light were studied on field grown plants of *Ilex opaca* Ait. cv. Miss Helen . Soluble D-fructose, α-D-glucose, B-D-glucose and sucrose reached a maximum concentration expressed as a percentage of the dry weight of leaf tissue during the winter sampling periods, followed by a decline as bud-expansion approached. The maximum concentration of soluble D-galactose was found in newly matured leaf tissue. Soluble D-fructose, α-D-glucose, B-D-glucose and sucrose levels were not effected by the shade environments. The level of D-galactose increased under the shaded environment as compared to full sun plants.

P and K levels in the leaf tissue were at high concentrations in newly matured leaf tissues, while Ca and Mg were at low levels. Both K and Mg levels were observed to be higher in leaf tissue from plants grown under the 92% shade conditions compared to full sun plants.

Stem diameter was significantly reduced under the 92% shade conditions, while leaf size of plants grown under both 50% and 92% shade was significantly increased. Flower production was significantly reduced in plants grown under the 92% shade conditions.

American Holly, *Ilex opaca* Ait., a native broadleaf evergreen tree of the Eastern United States has been a plant traditionally used for decorative effects at the Christmas season. At one time, annual sales of cut American holly exceeded one-half million dollars (7, 8). However, American holly sales have decreased considerably, due to several factors, including a decline in the supply of native holly, the superior quality of western grown English holly, and poor conservation practices; moreover, a primary cause has been the irregularity with which these trees flower and produce fruit in the native state (3). This research was initiated to investigate the influence of reduced light upon various growth responses and physiological conditions in an attempt to determine reasons for the irregularity in flowering and subsequent fruiting.

Materials and Methods

Nine, 6 year old female trees of *Ilex opaca* Ait. cv. 'Miss Helen' were planted in the fall of 1966 at the University of Delaware Substation Farm at Georgetown, Delaware, on a Plummer sandy loam soil. Three plants were allowed to receive full sunlight while the remaining 6 plants were enclosed in 5 X 5 X 5 ft structures and covered with saran cloth. One-half of these were covered with saran cloth designed to reduce the light intensity by 50% while the remaining plants were covered with similar material capable of reducing the light intensity by 92%. The plants were not fertilized during the course of the experiment, and were entirely dependent on native soil fertility for sustaining growth.

Leaf samples were collected monthly from the trees in July, August, and September of 1968. Bi-monthly collection of leaves was necessary from September 1968 until the completion of the study because of the limited number of leaves produced on those plants grown under the severe shade conditions. These leaf samples consisted of a random selection of approximately 25 leaves from the current season's growth. All leaves collected in the experimental period were produced in the growth flush of May, 1968. Each tree was treated as a single replicate for carbohydrate and mineral analysis.

Collected leaf tissues were dried in a forced air oven at 80°C for 3 to 5 days in order to insure uniform dryness, ground in a Wiley mill to pass a 20 mesh sieve, and stored in stoppered bottles. Soluble carbohydrates were determined by the method of Fretz, Dunham, and Woodmansee (6). Calcium, K, P and Mg were determined spectrophotometrically with a Technicon Auto Analyzer, after perchloric acid digestion[4]. Nitrogen was determined by routine Kjeldahl analysis as described by Chapman and Platt (4).

Leaf size was determined by selecting 5 leaves from each replication, tracing their outlines on paper, and determining the area with a K & E planimeter. Stem diameter measurements were obtained by driving a small brass nail into the base of each tree approximately four inches above the soil line on August 15, 1967, and measuring the diameters with a K & E steel diameter tape on several subsequent dates. The experiment was designed and statistically analyzed as a random block design with 3 replications. Statistical analyses were performed by an IBM

[1]Received for Publication June 22, 1970. Published as Misc. Paper No. 623 with the approval of the Director of the University of Delaware Agricultural Experiment Station. Contribution No. 12 of the Department of Plant Science. This paper is a portion of a Dissertation submitted by the senior author in partial fulfillment of the Doctor of Philosophy Degree.

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