**POSTHARVEST PRESERVATIVES**

# Effect of Captan, Isopropyl *N*-Phenylcarbamate, Isopropyl *N*-(3-Chlorophenyl)-carbamate, and Malathion on Keeping Quality of Plant Commodities in Storage

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Studies were made on the quality of apples, plums, tomatoes, carrots, and cabbage treated after harvest with captan, IPC, CIPC, and malathion dips and stored in laboratory-scale experiments. Attention was given to storage losses, bacterial and fungal decay, firmness, flavor, and general condition of the products. Captan somewhat improved the keeping quality of apples, plums, and tomatoes in storage, but its chemical injury to apples and its visible residue on the fruit surface were disadvantages. IPC and CIPC gave promising results on apples, plums, and tomatoes. They decreased fungal decay and retarded softening and color development on the fruits, thus extending their storage life. On carrots the effects of IPC and CIPC were variable; on cabbage they caused chemical injury and greatly accelerated decay. Malathion had no distinct effect on the plant products investigated.

RECENT research dealt with the stability of captan (*10*), isopropyl *N*-phenylcarbamate (IPC) and isopropyl *N*-(3-chlorophenyl)carbamate (CIPC) (*8*), and malathion (*9, 11*) on fruits and vegetables treated after harvest, their fate in food processing, and their degradation mechanism. In this paper the effects of these four chemicals on the keeping quality of fruits and vegetables in laboratory-scale storage experiments are reported. The quality of the plant commodity was measured on the basis of storage losses due to weight loss, microbial decay, physiological disorders, firmness, flavor, and general appearance.

## *Materials and Methods*

**Chemicals.** Four chemicals were employed in the following formulations:

Captan was used as Orthocide wettable powder containing 50 and 83% active ingredient (California Chemical S.A., Paris, France) and 50 and 80% formulations (California Chemical Co., Richmond, Calif.). In addition, the inactive ingredients with the same composition as in the French 50% formulation were tested on apples.

IPC and CIPC were prepared in emulsifiable concentrates: 40% w./w. technical IPC (FMC International, Ltd., New York, N. Y.) or CIPC (N.V. Fabriek van Chemische Producten, Vondelingenplaat, Holland), 8% Triton X-100, and 52% xylol.

Malathion was prepared in an emulsifiable concentrate: 60% w./w. premium grade malathion technical (American Cyanamid Co., New York, N. Y.), 8% Triton X-100, and 32% xylol.

**Application.** The chemicals were applied by dipping suitable portions of the plant material after harvest in 10 liters of dip solution (20° C.), prepared by diluting the basic formulation with water to the appropriate concentration. The materials were dipped for 30 seconds with constant agitation of the solution, then allowed to dry at room temperature for several hours. The control samples were dipped in tap water.

**Packing and Storage.** After having dried, the treated material was placed in two layers in cardboard boxes (31 × 47 × 14 cm.) on a layer of shredded parchment paper. The sides and cover had air holes for ventilation. Two replicate boxes, each containing 4 or 5 kg. of material taken at random, were stored from each treated lot; the amounts of the treated lots and of the control lot in each experiment were the same. The cabbage was stored in open wooden boxes lined with plastic film.

The trials were carried out at two temperatures: 2° ± 2° C. designated as "0° C." and 9° ± 2° C. designated as "10° C."; the relative humidity was 85 ± 5%. The cabbage was stored in an underground rock shelter at 5° ± 2° C.

**Residue Determination.** On most of the materials the amounts of chemical residues were determined at both the beginning and end of each trial. The analytical methods have been reported for captan (*10*), IPC and CIPC (*8*), and malathion (*7, 9*).

**External Appearance.** During storage, surface texture, color, glossiness, chemical injury, and general condition were visually examined.

**Decay Assays.** In many of the trials, decay during storage was assayed by counting the numbers of visibly damaged fruits or vegetables and calculating their share of the total. At the end of storage, the material of each lot was separated into two classes: "decayed," with visible damage making them unfit for trade, and "sound," suitable for the market. The percentage of these two classes was calculated. If necessary, additional classes were devised. The fungi occurring in the decayed fruit were identified and their damage was rated according to the percentage of fruit surface affected: "slight," 10% or less; "moderate," 10 to 25%; and "severe," more than 25% (*5*).

**Firmness Determinations.** At the end of certain trials, the firmness of the product in the sound class was determined either by the Spalt method using a N. Wolodkewitsch apparatus (Machine Laboratory, Technical School, Karlsruhe, Germany) or by measuring the resistance to surface puncturing or to pressure (*4*); 20 to 30 samples were measured for each determination.

**Flavor Tests.** For flavor evaluation, the sound plant material from both the treated and untreated lots was washed for 1 minute under running tap water, then either cut into small cubes or macerated into a mash. Each test consisted of a labeled standard of untreated plant material, three to five treated samples, and one "blind" standard. The members of the taste panel, composed of 10 to 20 persons, judged each sample in comparison to the labeled standard and reported their evaluation on a NE-15 score form used by Murphy *et al.* (*13*). A 5-point scale was used: 5, better than standard; 4, equal to standard; 3, below standard, but no off-flavor; 2, slight off-flavor; and 1, definite off-flavor. In addition, it was required that the off-flavor be identified.

The firmness and flavor results were tested by analysis of variance using $P = 0.05$ as criterion of significant difference.

### Table I. Storage Trials on Apples Treated after Harvest with Various Chemicals (1962–63)

| Treatment | Residue, P.P.M. | | Weight Loss, % | Sound, % | Decayed, % | Other Injury, % | Rel. Firmness[a] | No. of Decay Centers | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Gloesporium sp. | | | Penicillium expansum | | | Fusarium avenaceum | | |
| | Beginning | End | | | | | | Sl.[b] | Mod.[b] | Sev.[b] | Sl. | Mod. | Sev. | Sl. | Mod. | Sev. |
| Trial 1, Åkerö at 0° C., 4 1/2 Months | | | | | | | | | | | | | | | | |
| Tap water | ... | ... | 11 | 34 | 51 | 15 | 6.1 | 45 | 44 | 9 | 0 | 0 | 0 | 1 | 0 | 2 |
| Orthocide 83, 0.2% | 15.1 | 6.7 | 9 | 0 | 43 | 57 | 8.7[c] | 33 | 5 | 11 | 0 | 0 | 0 | 1 | 0 | 0 |
| IPC, 0.02% | 16.4 | 11.8 | 10 | 58 | 26 | 16 | 8.0[c] | 22 | 4 | 3 | 1 | 0 | 1 | 0 | 0 | 0 |
| CIPC, 0.02% | 29.2 | 19.5 | 10 | 66 | 19 | 15 | 7.0 | 21 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Malathion, 0.02% | 6.0 | 0.0 | 9 | 29 | 66 | 5 | 6.3 | 59 | 6 | 19 | 1 | 1 | 0 | 0 | 0 | 0 |
| Trial 2, Åkerö at 10° C., 3 Months | | | | | | | | | | | | | | | | |
| Tap water | ... | ... | 12 | 20 | 53 | 27 | 2.9 | 15 | 22 | 16 | 3 | 1 | 1 | 4 | 0 | 3 |
| Orthocide 83, 0.2% | 15.1 | 3.9 | 10 | 9 | 36 | 55 | 3.3 | 9 | 7 | 21 | 4 | 0 | 1 | 0 | 0 | 0 |
| IPC, 0.02% | 16.4 | 7.8 | 11 | 49 | 19 | 32 | 3.7 | 5 | 6 | 7 | 3 | 1 | 1 | 0 | 1 | 0 |
| CIPC, 0.02% | 29.2 | 15.2 | 11 | 52 | 23 | 25 | 3.0 | 10 | 4 | 10 | 0 | 0 | 0 | 0 | 0 | 2 |
| Malathion, 0.02% | 5.7 | 0.0 | 12 | 29 | 53 | 18 | 3.5 | 15 | 14 | 26 | 2 | 1 | 1 | 2 | 1 | 3 |
| Trial 3, Wealthy at 0° C., 4 1/2 Months | | | | | | | | | | | | | | | | |
| Tap water | ... | ... | 9 | 22 | 78 | ... | 3.0 | 49 | 29 | 24 | 0 | 0 | 1 | 1 | 4 | 3 |
| Orthocide 83, 0.2% | 17.4 | 7.8 | 9 | 32 | 68 | ... | 2.8 | 32 | 19 | 22 | 0 | 0 | 0 | 2 | 6 | 3 |
| IPC, 0.02% | 25.4 | 17.8 | 9 | 45 | 55 | ... | 3.3 | 39 | 18 | 11 | 0 | 0 | 0 | 3 | 1 | 2 |
| CIPC, 0.02% | 30.5 | 21.4 | 9 | 40 | 60 | ... | 3.5 | 40 | 17 | 6 | 1 | 0 | 0 | 6 | 4 | 2 |
| Malathion, 0.02% | 5.1 | 0.0 | 10 | 27 | 73 | ... | 3.2 | 45 | 23 | 14 | 0 | 0 | 0 | 5 | 3 | 8 |
| Trial 4, Wealthy at 10° C., 3 Months | | | | | | | | | | | | | | | | |
| Tap water | ... | ... | 12 | 27 | 73 | ... | 2.7 | 9 | 20 | 63 | 2 | 0 | 4 | 0 | 1 | 1 |
| Orthocide 83, 0.2% | 17.4 | 5.0 | 11 | 30 | 70 | ... | 2.9 | 1 | 23 | 58 | 1 | 0 | 4 | 1 | 0 | 3 |
| IPC, 0.02% | 25.4 | 13.9 | 11 | 62 | 38 | ... | 2.8 | 9 | 10 | 27 | 0 | 1 | 0 | 1 | 0 | 0 |
| CIPC, 0.02% | 30.5 | 21.9 | 11 | 70 | 30 | ... | 3.0 | 4 | 7 | 21 | 1 | 1 | 3 | 1 | 1 | 0 |
| Malathion, 0.02% | 5.9 | 0.0 | 13 | 41 | 59 | ... | 2.6 | 1 | 10 | 62 | 0 | 3 | 6 | 2 | 2 | 5 |

[a] Resistance to pressure.

[b] Decay classes according to % of surface affected. Sl. slight (<10%), Mod. moderate (10–25%), Sev. severe (>25%).

[c] Differs significantly ($P = 0.05$) from value obtained on control material treated with water.

## *Results and Discussion*

**Apples.** Two series of long-term storage trials were carried out on apples. In 1962–63 the effect of four postharvest chemicals on the keeping quality of the fruit was studied, and in 1963–64 determinations were made on the chemical injury caused by captan to the skin of apples.

The results of the first trial series are given in Table I.

Captan (Orthocide) slightly reduced fungal decay and kept the Åkerö variety apples firmer than the control. However, it very severely injured the skin of this variety and produced visible residual spots on the fruit surface.

IPC and CIPC had a favorable effect on the keeping quality of both apple varieties. The amounts of sound fruits in all the trials were about twice as high as in the control lots. The color and general condition were faultless, giving an impression of better quality than that of the untreated fruits. In all the trials the treated fruits were firmer than the control, although only on Åkerö treated with IPC was the difference statistically significant ($P = 0.05$). Both chemicals were distinctly able to reduce the decay caused by *Gloeosporium* spp. (*G. fructigena*, *G. album*, and *G. perennans*), but did not have a clear effect on *Pencillium expansum* or *Fusarium avenaceum*.

Malathion had no effect on the quality or storage life of apples.

Table II presents the results of the trials on the extent of injury caused to apple skin by captan. As the date of treatment was delayed, the chemical injury became more severe. This indicates that the formation of this disorder is associated with the state of ripening of apples. The same type of observation was reported by Gjaerum (*3*) on apples in Norway, and chemical injury to other fruits has also been mentioned (*1*, *6*, *15*).

**Plums.** Plums (var. Victoria) were harvested in the autumn of 1962 when they began to turn reddish and were treated with the four chemicals within 1 day.

The quality characteristics of stored plums are given in Table III. At both temperatures, fungal decay and internal browning were two factors causing damage to the fruit, but they were also appreciably affected by the chemicals.

Captan effectively protected plums from storage injury, especially by preventing the growth of *Mucor mucedo*, which was abundant in the control lots. The color of the captan-treated plums was similar to that of the control, but the visible residual spots from this chemical were a disadvantage.

IPC and CIPC were also effective antifungal agents, particularly against *M. mucedo* and *Sclerotinia fructigena;* at 10° C. CIPC seems to have promoted the development of *Penicillium expansum*. Both chemicals retarded softening at 0° C. and delayed color development at both temperatures. These two effects indicate that IPC and CIPC are closely involved in the metabolism of the fruit tissue (*2*, *14*, *16*). The flavor of IPC- and CIPC-treated plums did not differ from that of the control samples; some tasters, however, claimed the presence of a chemical off-flavor which might be attributed to xylol absorbed in the fruit skin rather than to the active ingredients.

Malathion-treated plums kept nearly as well as the control fruits. They were, however, somewhat softer, which may explain their lower score in the flavor test.

**Tomatoes.** Tomatoes (var. Grower's Pride) were harvested in the autumn of 1962 in two different states of maturity: mature-green and green. Correspondingly, two storage trials were carried out. The lots were treated within 1 week after harvest.

The results (Table IV) show that damage to tomatoes during storage was caused by fungal decay and by shriveling of the fruit skin.

Captan improved the keeping quality of the mature-green tomatoes but impaired that of green tomatoes. It reduced decay caused by *Penicillium expansum* and *Fusarium avenaceum;* it was ineffective against *Botrytis cinerea* on mature-green tomatoes, but accelerated its growth on green tomatoes. Color development was similar to that of the controls, but the visible residue detracted from the appearance of the fruits.

### Table II. Extent of Chemical Injury to Apples Treated with Captan and Stored at 3° ± 2° C. (1963–64)

| Date of Treatment | Treatment[a] | Chemical Injury[b] | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | After 3 Days | | | After 1 Month | | | March 3, 1964 | | |
| | | Canel | Åkerö | Wealthy | Canel | Åkerö | Wealthy | Canel | Åkerö | Wealthy |
| Sept. 25[c] | Tap water | − | − | − | − | − | − | − | − | − |
| | American Orthocide 50, 0.2% | + | − | − | + | ± | − | + | ± | − |
| | American Orthocide 80, 0.2% | +++ | − | − | ++++ | ± | − | ++++ | ± | − |
| | French Orthocide 50, 0.2% | + | − | − | + | ± | − | + | ± | − |
| | French Orthocide 0.2% | ++ | − | − | +++ | ± | − | +++ | − | − |
| | Inactive ingredients, 0.1% | − | − | − | − | − | − | − | − | − |
| Oct. 23[d] | French Orthocide 83, 0.2% | ... | − | + | ... | + | ++ | ... | + | +++ |
| Nov. 23[d] | French Orthocide 83, 0.2% | ... | + | ++ | ... | ++ | +++ | ... | ++ | ++++ |

[a] Initial residues varied from 3 to 15 p.p.m.
[b] Rating. +, slight; ++++, entire surface affected.
[c] Fruits kept in cold storage for 1 week prior to treatment.
[d] Fruits of same harvest lot as those treated Sept. 25 but stored in meantime at 0° C.

### Table III. Storage of Plums Treated after Harvest with Various Chemicals

| Treatment | Residue, P.P.M. | | Weight, Loss, % | Sound, % | Decayed, % | Brown Flesh, % | Rel. Firmness,[a] % | Flavor Score | No. of Decay Centers | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | Mucor mucedo | | | Sclerotinia fructigena | | | Penicillium expansum | | |
| | Beginning | End | | | | | | | Sl.[c] | Mod.[c] | Sev.[c] | Sl. | Mod. | Sev. | Sl. | Mod. | Sev. |
| | | | | | | Trial 1, 0° C., 6 Weeks | | | | | | | | | | | |
| Tap water | ... | ... | 7 | 22 | 48 | 30 | 2.0 | 3.0 | 0 | 0 | 69 | 0 | 0 | 19 | 1 | 0 | 0 |
| Orthocide 83, 0.5% | 12.8 | 10.5 | 4 | 74 | 6 | 20 | 1.7 | 3.4 | 0 | 0 | 0 | 0 | 12 | 0 | 0 | 0 | 0 |
| IPC, 0.1% | 43.4 | 31.6 | 5 | 80 | 5 | 15 | 2.5 | 3.1 | 0 | 0 | 4 | 4 | 0 | 0 | 0 | 0 | 0 |
| CIPC, 0.1% | 61.5 | 44.1 | 6 | 46 | 14 | 40 | 2.8 | 3.1 | 0 | 0 | 9 | 12 | 0 | 0 | 0 | 0 | 0 |
| Malathion, 0.5% | 3.0 | 0.0 | 6 | 29 | 56 | 15 | 1.6 | 2.5 | 0 | 0 | 61 | 0 | 0 | 35 | 0 | 2 | 0 |
| | | | | | | Trial 2, 10° C., 3 Weeks | | | | | | | | | | | |
| Tap water | ... | ... | 7 | 23 | 77[b] | ...[b] | 1.9 | ... | 0 | 0 | 83 | 0 | 0 | 34 | 0 | 7 | 0 |
| Orthocide 83, 0.5% | 12.8 | 10.6 | 4 | 70 | 30[b] | ...[b] | 1.9 | ... | 0 | 0 | 0 | 0 | 0 | 18 | 0 | 2 | 0 |
| IPC, 0.1% | 43.4 | 33.4 | 5 | 50 | 50[b] | ...[b] | 1.6 | ... | 0 | 0 | 21 | 0 | 0 | 16 | 0 | 10 | 0 |
| CIPC, 0.1% | 61.5 | 37.1 | 5 | 34 | 66[b] | ...[b] | 1.4 | ... | 0 | 0 | 2 | 0 | 0 | 17 | 0 | 59 | 0 |
| Malathion, 0.5% | 3.0 | 0.0 | 6 | 10 | 90[b] | ...[b] | 1.5 | ... | 0 | 0 | 42 | 0 | 0 | 38 | 0 | 13 | 0 |

[a] Spalt method.
[b] Plums with internal browning included in decayed group; their share was nearly same in all lots, about 20%.
[c] Decay classes according to % of surface affected. Sl. slight (<10%), Mod. moderate (10–25%), Sev. severe (>25%).

Shriveling of the skin was increased by captan.

IPC and CIPC improved the keeping quality of mature-green tomatoes but were ineffective or even slightly harmful to green tomatoes as a result of increased skin shriveling. These chemicals reduced decay caused by *P. expansum* in both trials and that by *B. cinerea* on mature-green tomatoes. Color development was somewhat slower than on the control fruits. Differences in firmness and flavor were small; however, CIPC retarded softening but impaired the flavor.

Malathion had no effect on the storage quality of tomatoes.

**Carrots.** Two trials were conducted, one in 1962–63 and the other in 1963–64. Carrots (var. Nantes) were harvested several days before treatment. The initial quality of the carrots used in the different trials was not uniform, and therefore only the results within the same trial are comparable. The main aim of these experiments was to study the extent of fungal and bacterial decay. For this purpose, some of the carrots were scratched by making four scratched lines 3 to 5 mm. wide along each carrot. The results are given in Table V.

Captan (Orthocide) was used only in trials 1 and 2. This chemical had no effect on the keeping quality of carrots nor on the pathogenic fungi.

IPC and CIPC did not give uniform results in respect to the amount of decay occurring. In trial 1 (0° C.) they slightly increased decay by accelerating the growth of *Sclerotinia sclerotiorum.* This effect was even more pronounced at the higher temperature in trial 2 (10° C.). In trial 4 at 0° C. CIPC caused severe damage as a result of the increased growth of *Botrytis cinerea* on the carrots whose surface had been scratched. At 10° C. (trial 5) IPC somewhat reduced the injury to scratched carrots. These results indicate that IPC and CIPC do not generally cause severe damage to intact carrots at 0° C., but if the storage temperature is higher or if the surface of the carrots is bruised, their effect on the storage life may be either positive or negative. At any rate, they nearly completely prevented sprouting of the carrots, as has been reported (*12*), and probably also retarded shriveling of the surface, thus maintaining a fresh appearance.

**Cabbage.** The outer leaves of cabbage heads (var. Fahlen Blue Tip) were removed and the heads treated with

## Table IV. Storage of Tomatoes Treated after Harvest with Various Chemicals

| Treatment | Residue, P.P.M. |  | Weight Loss, % | Sound, % | Decayed, % | Shriveled, % | Rel. Firmness,[a] % | Flavor Score | No. of Decay Centers |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|  |  |  |  |  |  |  |  |  | Penicillium expansum |  |  | Botrytis cinerea |  |  | Fusarium avenaceum |  |  | Stemphylium consortiala |  |  | Cladosporium sp. |  |  |
|  | Beginning | End |  |  |  |  |  |  | Sl.[b] | Mod.[b] | Sev.[b] | Sl. | Mod. | Sev. | Sl. | Mod. | Sev. | Sl. | Mod. | Sev. | Sl. | Mod. | Sev. |
| Trial 1, Mature-Green State at 10° C., 6 Weeks |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Tap water | . . . | . . . | 4 | 19 | 77 | 1 | 206 | 3.3 | 45 | 8 | 12 | 6 | 7 | 37 | 3 | 0 | 1 | 4 | 0 | 1 | 0 | 1 | 0 |
| Orthocide 50, 0.5% | 2.6 | . . . | 5 | 50 | 41 | 9 | 159 | 3.6 | 33 | 10 | 5 | 0 | 1 | 26 | 0 | 0 | 0 | 10 | 0 | 0 | 0 | 0 | 0 |
| IPC, 0.2% | 70.9 | 50.4 | 5 | 66 | 27 | 7 | 191 | 3.0 | 26 | 6 | 4 | 0 | 4 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| CIPC, 0.2% | 70.0 | 47.4 | 5 | 52 | 43 | 5 | 226 | 2.6 | 48 | 8 | 6 | 6 | 0 | 4 | 6 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| Malathion, 0.5% | 2.4 | 0.0 | 4 | 25 | 72 | 3 | 197 | 3.3 | 50 | 15 | 13 | 2 | 7 | 36 | 0 | 0 | 0 | 2 | 2 | 1 | 13 | 4 | 1 |
| Trial 2, Green State at 10° C., 7 Weeks |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| Tap water | . . . | . . . | 6 | 54 | 46 | . . . | 474 | . . . | 37 | 5 | 21 | 5 | 2 | 13 | 1 | 1 | 7 | 2 | 0 | 0 | 0 | 1 | 2 |
| Orthocide 50, 0.5% | 12.0 | 6.2 | 8 | 27 | 73 | . . . | 453 | . . . | 6 | 0 | 0 | 9 | 6 | 120 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 |
| IPC, 0.2% | 105.8 | 80.3 | 7 | 51 | 51 | . . . | 495 | . . . | 24 | 2 | 8 | 7 | 4 | 31 | 0 | 0 | 0 | 1 | 1 | 0 | 2 | 1 | 1 |
| CIPC, 0.2% | 132.7 | 112.2 | 7 | 52 | 52 | . . . | 517 | . . . | 17 | 3 | 7 | 9 | 1 | 42 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| Malathion, 0.5% | 3.9 | 0.0 | 6 | 45 | 45 | . . . | 423 | . . . | 35 | 4 | 10 | 2 | 4 | 38 | 1 | 1 | 1 | 3 | 1 | 0 | 2 | 0 | 2 |

[a] Resistance to surface puncturing.

[b] Decay classes according to % of surface affected. Sl. slight (<10%), Mod. moderate (10-25%), Sev. severe (>25%).

Orthocide 83, IPC, and CIPC dips (0.2% concentrated). They were stored in lots of 17 heads for 2 months.

After 2 weeks of storage the control and captan-treated heads were faultless, but the IPC- and CIPC-treated heads had large areas of dark-color lesions, indicating death of the surface tissues. At the end of the trials about one half of the control heads (9 out of 17) showed no injury, while the rest had only slight bacterial damage in the outermost leaf layers. The captan-treated cabbages were more severely affected by bacteria and fungi (*Botrytis cinerea*) than the controls; out of 17 heads, six were entirely sound, five had damage in the surface leaves, and six were damaged also in the interior. All of the IPC- and CIPC-treated cabbages showed damage caused by chemical injury as well as microorganisms—e.g., *Botrytis cinerea* and *Penicillium sp.* These disorders also extended to the interior leaves, and six heads (for each of the chemicals) were completely decayed.

## Conclusions

Captan slightly reduced the fungal decay of apples, but it caused a chemical injury which—together with the visible residues remaining on the surface—detracted from the appearance of the fruit. The chemical injury was more pronounced as the ripening state of the fruits advanced. Captan proved to be in these trials unfit for postharvest use on apples. On plums and mature-green tomatoes, captan suppressed the growth of some fungi and thus reduced storage losses, but the visible residue harmed their appearance. This chemical had no observable effects on carrots; on cabbage it increased bacterial and fungal damage.

The effects of IPC and CIPC were generally very similar. They improved the keeping quality of apples, plums, and mature-green tomatoes and in many cases greatly reduced the storage losses. Both chemicals tended to delay both softening and color development of plums and tomatoes in storage. The results indicate that IPC and CIPC have promising uses as postharvest chemicals on the above fruits. On carrots the effects of these compounds varied considerably, and thus no definite conclusions can be made in this regard; they did, however, inhibit sprouting of carrots. On cabbage IPC and CIPC caused severe chemical injury and consequently greatly shortened the life of this commodity.

Malathion treatment had no distinct effect on the storage qualities of any of the plant products tested.

This study is not intended to encourage the postharvest use of these chemicals unless they are officially approved for that purpose in the country concerned.

## Table V. Storage of Carrots Treated after Harvest with Various Chemicals

| | | | | | No. of Decay Centers | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | *Botrytis cinerea* | | | *Sclerotinia sclerotiorum* | | | *Stemphylium radicinum* | | | *Penicillium expansum* | | | *Mucor sp.* | | | Bacteria | | |
| Treatment | Surface | Weight Loss, % | Sound, % | Decayed, % | Sl.[a] | Mod.[a] | Sev.[a] | Sl. | Mod. | Sev. | Sl.[a] | Mod.[a] | Sev.[a] | Sl. | Mod. | Sev. | Sl. | Mod. | Sev. | Sl. | Mod. | Sev. |
| Trial 1, 0° C., 16 Weeks | | | | | | | | | | | | | | | | | | | | | | |
| Tap water | Intact | 22 | 56 | 44 | 10 | 0 | 2 | 26 | 4 | 3 | 13 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 |
| Orthocide 83, 0.2% | Intact | 18 | 50 | 50 | 3 | 1 | 5 | 10 | 4 | 27 | 7 | 1 | 0 | 0 | 0 | 0 | 1 | 2 | 0 | 0 | 0 | 0 |
| IPC, 0.2% | Intact | 19 | 40 | 60 | 9 | 0 | 2 | 18 | 7 | 41 | 9 | 0 | 1 | 4 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 4 |
| CIPC, 0.2% | Intact | 24 | 24 | 76 | 9 | 0 | 1 | 38 | 8 | 40 | 10 | 2 | 0 | 4 | 0 | 0 | 0 | 1 | 0 | 2 | 1 | 4 |
| Trial 2,[b] 10° C., 7 Weeks | | | | | | | | | | | | | | | | | | | | | | |
| Tap water | Intact | 14 | 57 | 43 | | | | | | | | | | | | | | | | | | |
| Orthocide 83, 0.2% | Intact | 14 | 48 | 52 | | | | | | | | | | | | | | | | | | |
| IPC, 0.2% | Intact | 18 | 8 | 92 | | | | | | | | | | | | | | | | | | |
| CIPC, 0.2% | Intact | 17 | 21 | 79 | | | | | | | | | | | | | | | | | | |
| Trial 3, 0° C., 24 Weeks | | | | | | | | | | | | | | | | | | | | | | |
| Tap water | Intact | 32 | 80 | 20 | | | | | | | | | | | | | | | | | | |
| | Scratched | 36 | 57 | 43 | | | | | | | | | | | | | | | | | | |
| IPC, 0.2% | Intact | 35 | 70 | 30 | | | | | | | | | | | | | | | | | | |
| | Scratched | 38 | 72 | 28 | | | | | | | | | | | | | | | | | | |
| Trial 4, 0° C. 24 Weeks | | | | | | | | | | | | | | | | | | | | | | |
| Tap water | Intact | 31 | 94 | 6 | | | | | | | | | | | | | | | | | | |
| | Scratched | 31 | 79 | 21 | | | | | | | | | | | | | | | | | | |
| CIPC, 0.2% | Intact | 27 | 87 | 13 | | | | | | | | | | | | | | | | | | |
| | Scratched | 31 | 12 | 88[c] | | | | | | | | | | | | | | | | | | |
| Trial 5, 10° C., 9 Weeks | | | | | | | | | | | | | | | | | | | | | | |
| Tap water | Intact | 24 | 68 | 32 | | | | | | | | | | | | | | | | | | |
| | Scratched | 27 | 0 | 100 | | | | | | | | | | | | | | | | | | |
| IPC, 0.2% | Intact | 25 | 68 | 32 | | | | | | | | | | | | | | | | | | |
| | Scratched | 28 | 42 | 59 | | | | | | | | | | | | | | | | | | |
| Trial 6, 10° C., 9 Weeks | | | | | | | | | | | | | | | | | | | | | | |
| Tap water | Intact | 30 | 82 | 18 | | | | | | | | | | | | | | | | | | |
| | Scratched | 22 | 58 | 42 | | | | | | | | | | | | | | | | | | |
| CIPC, 0.2% | Intact | 20 | 78 | 22 | | | | | | | | | | | | | | | | | | |
| | Scratched | 22 | 66 | 34 | | | | | | | | | | | | | | | | | | |

[a] Decay classes according to % of surface affected: Sl. slight (<10%), Mod. moderate (10–25%), Sev. severe (>25%).

[b] Trials 2 to 6 not determined.

[c] Decay caused mainly by *Botrytis cinerea.*

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**POSTHARVEST PRESERVATIVES**

# Magnitude and Stability of Captan Residues in Fresh and Preserved Plant Products

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The behavior of captan residues on several plant commodities dip-treated after harvest in a captan suspension was studied; the residues were determined colorimetrically. Dipping as an application method was tested with respect to the uniformity of residues and the effect of dip concentration, dipping time, and size of fruit on the amount of initial deposits. On stored strawberries, gooseberries, string beans, tomatoes, plums, and apples, captan had a long residual life. Losses of captan residues were also studied during various preservation processes. If the process included a heating phase, the losses were usually over 90%. Losses in freezing without blanching were much lower (10 to 50%), and the residues on frozen products were stable for several months of storage. Washing plant products in running water just after dipping or after 1 week of storage resulted in 17 to 85% losses.

Captan, *N*-(trichloromethylthio)-4-cyclohexene-1,2-dicarboximide, has proved to be a superior fungicide and is extensively used against many diseases of fruits and vegetables. It is also an effective seed disinfectant. In addition to being a preharvest pesticide, captan also has a wide use as a postharvest chemical (*18*). Numerous studies have shown that either pre- or postharvest treatment with captan improves the keeping quality of fruits in storage—e.g., apples (*5, 6, 13, 14, 28*), pears (*20*), peaches (*9, 24, 25*), strawberries (*1, 16, 17, 21, 29, 31*), and grapes (*2, 8*). Because of the low toxicity of this chemical, its FDA tolerance limit in the United States is as high as 100 p.p.m. (*18*).

There are only a few reports in the literature on the magnitudes of captan residues and their disappearance. The investigations published (*7, 15, 26*) indicate that the residues are persistent but are readily destroyed during heating (*3, 15, 22*).

The aim of the present study was to determine the magnitude and stability of captan residues on plant commodities treated after harvest by dipping and to measure the captan losses occurring during food processing.

### Materials

Captan was used in the form of Orthocide 83 wettable powder (California Chemical S. A., France). For constructing the standard calibration curve, however, purified (99%) captan (California Chemical Co., Richmond, Calif.) was used.

The following raw plant commodities were tested: strawberries (vars. Ydun and Senga Sengana), gooseberries (var. Houghton), tomatoes (vars. Selantia and Grower's Pride), plums (var. Victoria), apples (vars. Wealthy and Åkerö), and string beans (var. Hinrichs Kaenpe). In the residue stability experiments, the fruits were not completely ripe at the beginning of the trials, whereas in the preservation and washing trials they were harvest-ripe at the time of captan treatment. The stipes of the fruits (and the perianth remnants of the gooseberries) were not removed.

### Analytical Methods

Captan residues were extracted from the unmacerated samples with benzene alone or, for avoiding emulsions, from the macerated samples with ethanol as a cosolvent. The extraction and cleanup procedures with activated charcoal were those employed for malathion residues (*11*). Captan was determined colorimetrically by the method of Kittleson (*10*) as applied by Taylor and Klayder (*30*); a yellow color is developed by fusion of the captan with resorcinol at 135° C. and by dissolving the mixture in glacial acetic acid.