Comparison of Sensory Differences of Stored Russet Burbank Potatoes Treated with CIPC and Alternative Sprout Inhibitors

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ABSTRACT

The sensory properties of Russet Burbank potatoes treated with three naturally occurring volatile compounds, as alternatives to CIPC for sprout inhibition, were evaluated. Potatoes from the 1995 and 1996 crop years were treated with salicylaldehyde, 1,8-cineole, 1,4-dimethylnaphthalene, or CIPC prior to dormancy break during storage and stored for up to 16 wk. Sensory differences between potatoes treated with alternative sprout inhibitors and CIPC-treated or untreated potatoes and inhibitor concentration were determined at 2-wk intervals. Potatoes treated with 1,8-cineole or salicylaldehyde, but not 1,4-dimethylnaphthalene, were significantly different from the untreated potatoes or potatoes treated with CIPC. Sensory detection threshold levels for the alternative inhibitors were measured in a model potato system. The residual levels of the sprout inhibitors were within the detection threshold range for 1,8-cineole (0.02-0.04 ppm), but not for salicylaldehyde (0.09 – 0.10 ppm) or 1,4-dimethylnaphthalene (0.80-1.40 ppm). The presence of the residual sprout inhibitors and/or the influence of sprout inhibitors on potato metabolism during storage contributed to observed differences in sensory quality of stored potatoes.

RESUMEN

Se evaluaron las propiedades sensoriales de la variedad Russet Burbank con tres compuestos volátiles que ocurren naturalmente, como alternativas al CIPC para la inhibición de la germinación. Las papas de las compañas de 1995 y 1996 fueron tratadas con salicilaldehído, 1,8-cineol, 1,4-dimetilnaftaleno y CIPC antes de perder la dormancia y luego almacenadas por más de 16 semanas. Las diferencias sensoriales entre las papas tratadas con inhibidores alternativos de germinación y CIPC, y las papas no tratadas y la concentración del inhibidor fueron determinadas con intervalos de dos semanas. Las papas tratadas con el 1,8-cineol o salicilaldehído, pero no con el, 1,4-dimetilnaftaleno, fueron signifciativamente diferentes de las papas no tratadas o de las papas tratadas con CIPC. Los niveles del umbral de detección sensorial de los inhibidores altarnativos se midieron en un sistema modelo de papa. Los niveles residuales de los inhibidores de germinación estuvieron dentro del rango del umbral de detección para el 1,8-cineole (0.02-0.04 ppm), pero no para el salicilaldehído (0.09-0.10 ppm) o el 1,4-dimetilnaftaleno (0.80-1.40 ppm). La presencia de inhibidores residuales de germinación y/o la influencia de los inhibidores de germinación en el metabolismo de la papa durante el almacenamiento contribuyó a las diferencias observadas en la calidad sensorial de las papas almacenadas.

INTRODUCTION

The storage life of potatoes is extended through the use of sprout inhibitors so that high quality potatoes are available to the consumer year around. Currently, isopropyl-N-chlorophenyl carbamate (CIPC) is widely used in the U.S. to inhibit potato

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Abbreviations:
CIN: cineole
CIPC: isopropyl-N-chlorophenyl carbamate
DMN: 1,4-dimethyl naphthalene
EC: emulsifiable concentrate
SAL: salicylaldehyde

sprouting during storage. However, CIPC is a weak toxin and concerns regarding the toxicity and safety of CIPC have contributed to interest in the identification of natural compounds that are effective in the inhibition of potato sprouting (Gartrell *et al.* 1986). Naturally occurring volatile compounds, including monoterpenes, aromatic aldehydes, naphthalene derivatives, and other naturally occurring aromatic compounds have been evaluated for their ability to inhibit potato sprouting during storage (Meigh 1969; Meigh *et al.* 1973; Beveridge *et al.* 1981a,b; Vaughn and Spencer 1991, 1992; Vokou *et al.* 1993; Daniels-Lake *et al.* 1996; Yang *et al.* 1999). Three compounds, 1,4-dimethylnaphthalene, cineole, and salicylaldehyde, have been identified as promising alternatives to CIPC because of their effective sprout-inhibiting effect, low residue, and low toxicity (Meigh *et al.* 1973; Beveridge *et al.* 1981b; Vaughn and Spencer 1991, 1992; Daniels-Lake *et al.* 1996). Although the effectiveness of these compounds has been established, the effect of these compounds on the sensory quality and composition of the stored potatoes has not been determined. For these natural sprout inhibitors to be viable alternatives to CIPC, it must be demonstrated that the compounds do not have any adverse effects on the sensory properties, and hence consumer acceptability, of the potatoes and processed potato products.

The objective of this research was to determine the impact of treating potatoes with three alternative sprout inhibitors, salicylaldehyde, 1,8-cineole, and 1,4- dimethylnaphthalene, on the sensory properties of potatoes. The potatoes were stored for up to 16 weeks and baked prior to sensory evaluation and quantitation of the sprout inhibitor. Sensory tests were conducted to determine if panelists could detect differences between potatoes treated with the sprout inhibitors and untreated or CIPC-treated potatoes. To further study the effect of the sprout inhibitors on sensory properties of potato products, a model system was developed to evaluate the detection threshold of the alternative sprout inhibitors in mashed potatoes.

MATERIALS AND METHODS

Materials

Fresh potatoes (*Solanum tuberosum* cv Russet Burbank) were provided by Sun- Spiced, Basic American Foods, Moses Lake, WA. Whipped potato matrix for the sensory threshold study was prepared from Betty Crocker Potato Buds, General Mills, Minneapolis, MN. Salicylaldehyde and 1,8-cineole were purchased from Aldrich Chemical Co., Milwaukee, WI. 1,4-Dimethylnaphthalene (DMN) and 1,4- dimethylnaphthalene emulsifiable concentrate (DMN-EC) were provided by PIN/NIP Inc., Meridian, ID. Isopropyl N-(3-chlorophenyl) carbamate emulsifiable concentrate (CIPC) was obtained from Platte Chemical Company, Fremont, NE. The internal standard, tridecane, was purchased from Alltech Associates, Inc., Deerfield, IL.

Sensory Evaluation Protocol

Duo-trio sensory tests were conducted in this study to determine the detection threshold of alternative sprout inhibitors and to determine the effect of alternative sprout inhibitors on sensory differences of baked potatoes. Panelists were faculty, staff, and students in the Department of Food Science and Human Nutrition and College of Agriculture and Home Economics at Washington State University. Many of the panelists had experience with sensory evaluation, but were not screened for threshold or trained for the evaluations conducted. The Institutional Review Board of the Office of Grant and Research Development at Washington State University approved the procedures, compounds used in the sensory tests as safe for human consumption, and participation of human subjects. Informed consent was received from each panelist prior to evaluation of the samples.

Threshold Study

Sample Preparation—To determine the detection threshold of the sprout inhibitor compounds, inhibitors were added to a whipped potato matrix prepared from commercially available instant potato buds. A mixture of 18% dry potato buds in boiling water was whipped using a Hobart mixer (Model C100-T) for 3 min to prepare matrix for treatment compounds and 5 min for untreated reference samples. Treatment samples were whipped for an additional 2 min after addition of sprout inhibitor compounds. Treatments included (1) salicylaldehyde at 0.005, 0.010, 0.050, 0.10, 0.20, and 0.40 ppm; (2) 1,8- cineole at 0.005, 0.015, 0.030, 0.060, 0.090, and 0.120 ppm; and (3) 1,4-dimethylnaphthalene (DMN) at 0.20, 0.40, 0.80, 1.50, 3.00, and 5.00 ppm.

Sensory Evaluation—Duo-trio sensory tests were conducted on the six levels of each sprout inhibitor compound in whipped potatoes. Samples (approximately 30 g) were placed in beakers and covered with polyfilm. Prior to serving, samples were heated to 42-44 C in a 0.6 cu ft, 600W microwave oven (Emerson Radio Corporation, Parsippany, NJ) for 15 sec on 'High' setting. Samples were evaluated under red light.

Thirty to thirty-four panelists participated in each sensory test. The test samples consisted of a treated and reference untreated sample. In each session, panelists compared an

untreated whipped potato reference to whipped potato treated with increasing levels of an individual sprout inhibitor. Each sample set included the untreated constant reference labeled "Ref," and two test samples (treated and untreated) labeled with a three-digit random code. Panelists were asked to identify the sample that was different from the reference. Panelists were provided with unsalted soda crackers and distilled water for oral rinsing between samples. Order of sample presentation was balanced and randomized. Each sensory test was replicated three times.

Geometric mean of the group best estimate threshold (BET) for each inhibitor was calculated as described by Meilgaard *et al.* (1999). Inhibitor thresholds are reported as the range between the difference threshold (concentration at which a difference was noted in 60% of the trials) (ASTM Committee E 18 on Sensory Evaluation 1979) and the group geometric mean.

Storage Study

Sample Preparation—Fresh Russet Burbank potatoes grown in central Washington State were harvested in mid-September in 1995 and mid-October in 1996. Potato plants and tubers had not been treated with growth regulators or sprout inhibitors.

Potatoes were suberized at 10 C for 30 days before storage at 7 C, 95% R. H. Inhibitors were applied at 20 wk after harvest in 1995 and 16 wk after harvest in 1996. Average tuber sizes were 400 g and 244 g for 1995 and 1996, respectively. Inhibitors were applied according to the method reported by Yang *et al.* (1999). Aerosol heat application was used for treatment of potatoes with 200 ppm salicylaldehyde, 100 ppm 1,8-cineole and 40 and 80 ppm 1,4-dimethylnaphthalene (DMN and DMN 2x). Emulsifiable concentrates DMN-EC (40 ppm) and CIPC (11 ppm) were applied as a spray. The amount of inhibitor applied was based on fresh potato weight. Treated tubers in individual polyethylene containers were stored at 7 C and 95% R.H. for up to 16 wk. During storage, a vacuum pump located outside the storage room circulated ambient air through the closed containers at 0.198 m^3/min (Yang *et al.* 1999).

Sensory Evaluation—In a duo-trio sensory test, 24 panelists compared untreated control tubers or CIPC-treated tubers to potatoes treated with test inhibitor compounds after 2, 4, 6, 8, and 16 wk storage at 7 C, 95% R.H. Tests of untreated control tubers were discontinued after 6 or 8 wk due to sprouting and desiccation. Potato tubers were removed from storage containers and held at room temperature (~22 C) overnight. Sprouts, if present, were removed, and potatoes were cleaned using a dry vegetable brush. Potatoes were individually wrapped in aluminum foil and baked at 400 F (204 C) for 105 min in a conventional oven. Baked potatoes were divided into sections of approximately 30 g. The center portions, the inner parenchyma and pith, accounting for 40 to 50% of the total tissue, were excluded from the sample. Potatoes treated with salicylaldehyde, 1,8-cineole, or 1,4-dimethylnaphthalene were compared to either CIPC-treated or untreated reference in one test session, and DMN 2x and DMN-EC were compared to the CIPC and untreated references in a second session. The number of sample sets presented to a panelist in one session was limited to three to prevent sensory fatigue. Treatment replicates were presented at separate sessions on alternating dates. Lighting, serving temperature, and order of presentation were as described above.

Inhibitor Analysis—Headspace purge-and-trap methods were used for the isolation of the alternative sprout inhibitors from the peel and cortex portions of stored and baked potatoes. Potatoes (100 g) were chopped and placed in a 500-ml, two-neck round-bottom flask with 100 ml deionized water. Tridecane (internal standard, 12.5 µg) was added to the flasks prior to isolation. Volatile compounds were isolated from the potato matrix through the use of continuous nitrogen purging in conjunction with the application of a vacuum and trapping on a Tenax trap. The isolation was carried out at 40 C for 5 h for the stored potatoes and at 70 C for 4 h for the baked potatoes. The volatiles were eluted from the traps with 15 ml hexane (HPLC grade), concentrated to 200 µl under a stream of nitrogen, and analyzed by gas chromatography. The volatile flavor compounds were separated on a 100% dimethylpolysiloxane capillary column (SE-30, 30 m, 0.32 mm Alltech Associates, ID) installed in a gas chromatograph (Model 3400, Varian Associates, Inc., Walnut Creek, CA) equipped with a flame ionization detector and on-column injection port. Contents of the individual volatile compounds were calculated based on the recovery of the internal standard and quantities of potato tissue and internal standard, based on a standard curve for tridecane. Identification of the volatile compounds was based on comparison of GC retention times to pure commercial standards (Boylston *et al.* 1994).

Statistical Analysis

Statistical significance of sensory test results for baked potatoes was determined from tables by Roessler *et al.* (1978). Comparison of inhibitors recovered in the stored (raw) potatoes and baked potatoes was performed by PROC GLM in SAS as a 2 x 5 factorial with type (raw vs. baked) and time (2, 4, 6, 8, and 16 wk in storage) as the main factors for each natural inhibitor. Main

effect differences were considered significant at the P = <0.05 level. Means separations were determined by Fisher's Least Significant (LSD) test for multiple comparisons (SAS Institute, Inc. 1993). Means from the two crop years are presented separately.

RESULTS AND DISCUSSION

The alternative sprout inhibitors evaluated in this study have unique aroma and flavor characteristics. Therefore, there is concern that the use of these compounds as sprout inhibitors may impart uncharacteristic or undesirable flavors to the potatoes if the residual levels in the potatoes following treatment and storage exceed the sensory detection threshold of the compounds. Sensory detection thresholds determined in this study and aroma descriptions of the alternative sprout inhibitors (Aldrich 1998) are shown in Table 1.

Following treatment of the potatoes with volatile sprout inhibitors, concentrations in the stored potatoes decreased significantly (Figure 1), with the greatest losses occurring in the initial 2 wk of storage. The volatility of these sprout inhibitors

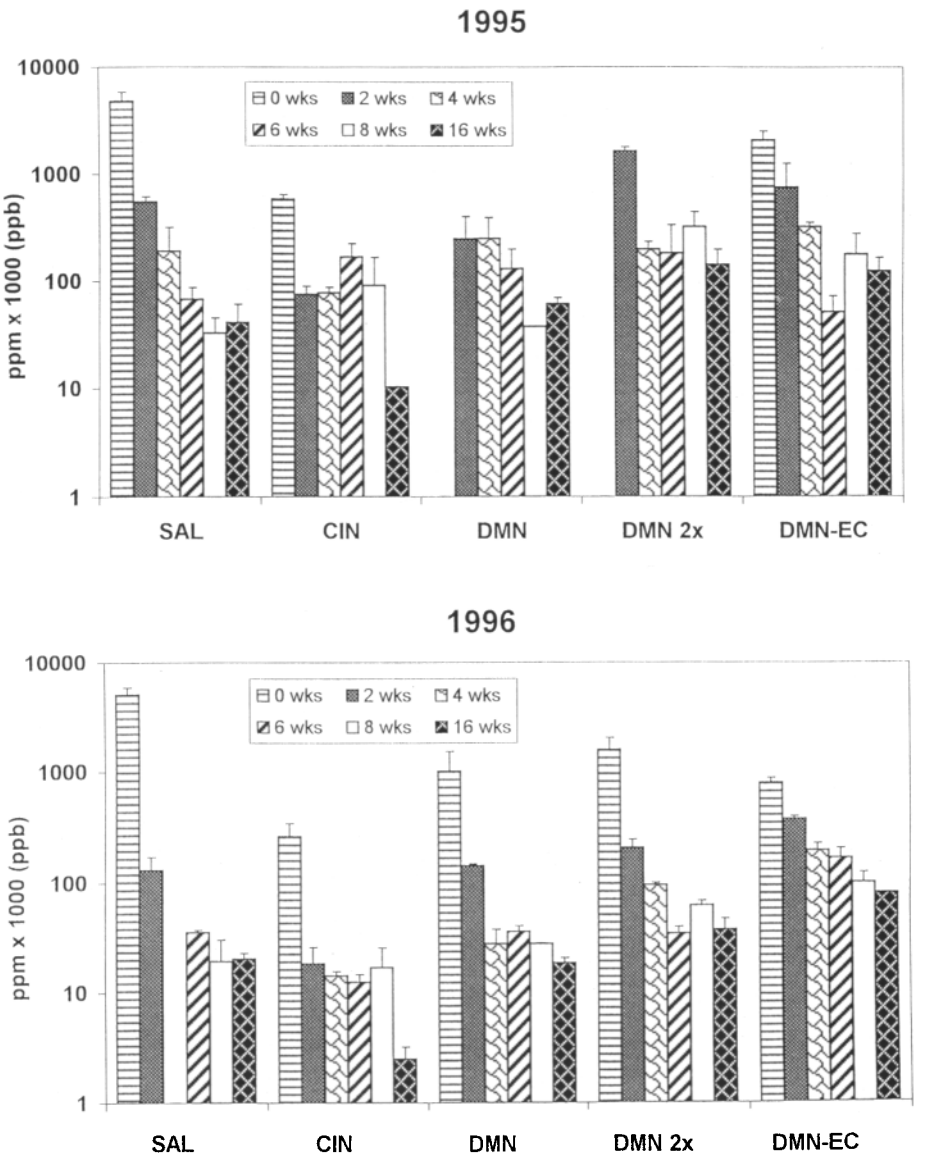

FIGURE 1.
Inhibitor concentration in Russet Burbank Potatoes stored at 7 C, 95% R.H. for 16 wk. Note value (y) axis is logarithmic scale. Heat aerosol treatments prior to storage: SAL = 200 ppm salicylaldehyde; CIN = 100 ppm cineole; DMN = 40 ppm 1,4 dimethylnaphthalene; DMN 2x = 80 ppm 1,4 dimethylnaphthalene. DMN-EC = 40 ppm 1,4 dimethylnaphthalene emulsifiable concentrate applied as a spray. Note 1996 data for salicylaldehyde stored 4 wks not available. Error bars are standard deviation of the mean.

TABLE 1.—*Sensory detection thresholds of alternative sprout inhibitors.*

Compound	Threshold (ppm)	Aroma Description[1]
1,8-Cineole	0.02-0.04	camphoraceous, cool, spicy
Salicylaldehyde	0.09-0.10	pungent, phenolic odor, spicy, almond taste
1,4-Dimethylnaphthalene	0.80-1.40	earthy, phenolic

[1]Aldrich (1998).

would contribute to the observed decreases in inhibitor concentrations. Further decreases in sprout inhibitor concentration were observed with baking for all inhibitors, except salicylaldehyde (Table 2). Variability in the ability of salicylaldehyde, 1,8-cineole, and 1,4-dimethylnaphthalene to penetrate the skin and migrate into the tuber could account for the observed cooking effects. Since the potatoes were wrapped in aluminum foil during baking, volatilization of the sprout inhibitors would be expected to be less than if potatoes were baked unwrapped.

To determine the effect of the alternative sprout inhibitors on baked potatoes, potatoes treated with alternative sprout inhibitors prior to storage were compared with reference (untreated or CIPC-treated) potatoes using duo-trio difference testing. The function of the duo-trio difference test is to determine whether an overall difference exists between two samples with no specific attribute identified. A difference between two samples exists if the number of correct judgements exceeds the minimum number of correct responses determined based on probability tables (Roessler *et al.* 1978). For 24 panelists, 17 panelists (71%) must correctly identify the sample identical to the reference sample for the treatments to be considered significantly different. The impact of the inhibitors on the sensory properties of the treated potatoes in comparison to the reference potatoes varied depending on the inhibitor. Differences in

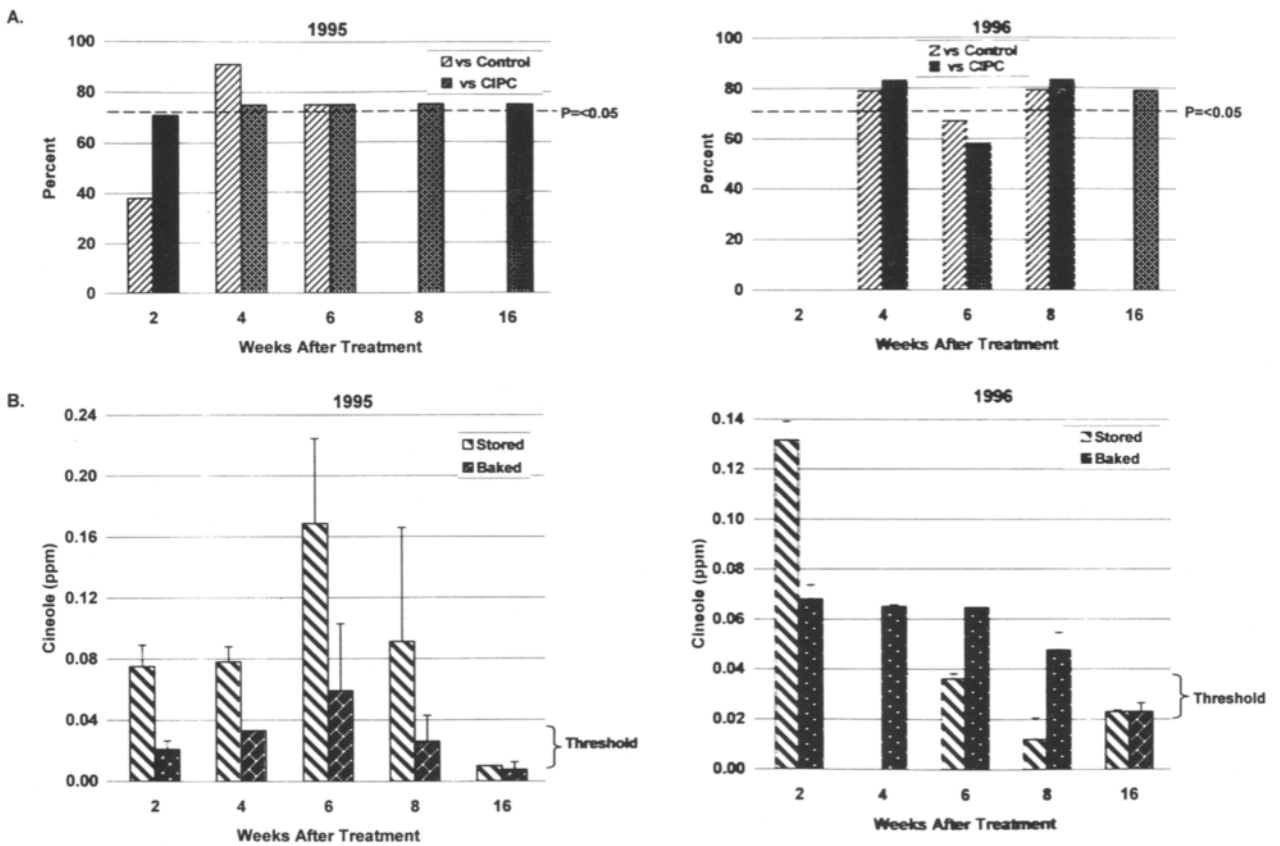

FIGURE 2.
Sensory and analytical results for tubers treated with 100 ppm cineole by heat aerosol prior to storage at 7 C, 95% R.H. for 16 wk. (A.) Sensory results indicating the proportion of panelists correctly identifying the treated baked potatoes as different from reference baked potatoes. Level of significance is set at P = <0.05. (B.) The concentration of cineole detected in stored and baked potatoes. Brackets indicate the sensory threshold of cineole. Note 1996 data for tubers stored 4 wk not available. Error bars are standard deviation of the mean.

TABLE 2.—*Effect of baking on sprout inhibitor content (ppm) of treated potatoes.*

	Crop year			
	1995		1996	
Compound	Stored	Baked	Stored	Baked
Salicylaldehyde (200 ppm)[1]	0.197[a]	0.176[a]	0.052[a]	0.052[a]
Cineole (100 ppm)[1]	0.093[a]	0.020[b]	0.013[a]	0.006[b]
1,4 Dimethylnaphthalene (40 ppm)[1]	0.162[a]	0.074[b]	0.050[a]	0.008[b]
1,4 Dimethylnaphthalene (80 ppm)[1]	0.499[a]	0.090[b]	0.088[a]	0.013[b]
1,4 Dimethylnaphthalene-EC (40 ppm)[2]	0.289[a]	0.093[b]	0.183[a]	0.016[b]

[1]Heat aerosol application.
[2]Spray application of emulsion .
[a,b]For separate years and inhibitors, means followed by the same letter are not significantly different (P = <0.05). Means are pooled over the storage period.

the results of the sensory evaluation for crop years 1995 and 1996 may be attributed to differences in the effectiveness in the application of the inhibitors to the potatoes, potato size, and time of treatment following harvest (Figures 2-5).

Potatoes treated with cineole were significantly different from the reference potatoes throughout the 16-wk storage period (Figure 2). The sensory detection threshold (0.02-0.04 ppm) established for cineole was within the concentration range of cineole (0.003 - 0.059 ppm; Figure 2) in the baked potatoes throughout the storage period. Daniels-Lake *et al.* (1996) also noted that the aroma of cineole in potatoes treated at 150 ppm persisted through processing and frying.

Potatoes treated with 1,4-dimethylnaphthalene were not judged significantly different from the reference potatoes throughout the storage period (Figures 3 and 4). The residual levels of 1,4-dimethylnaphthalene in the potato following bak-

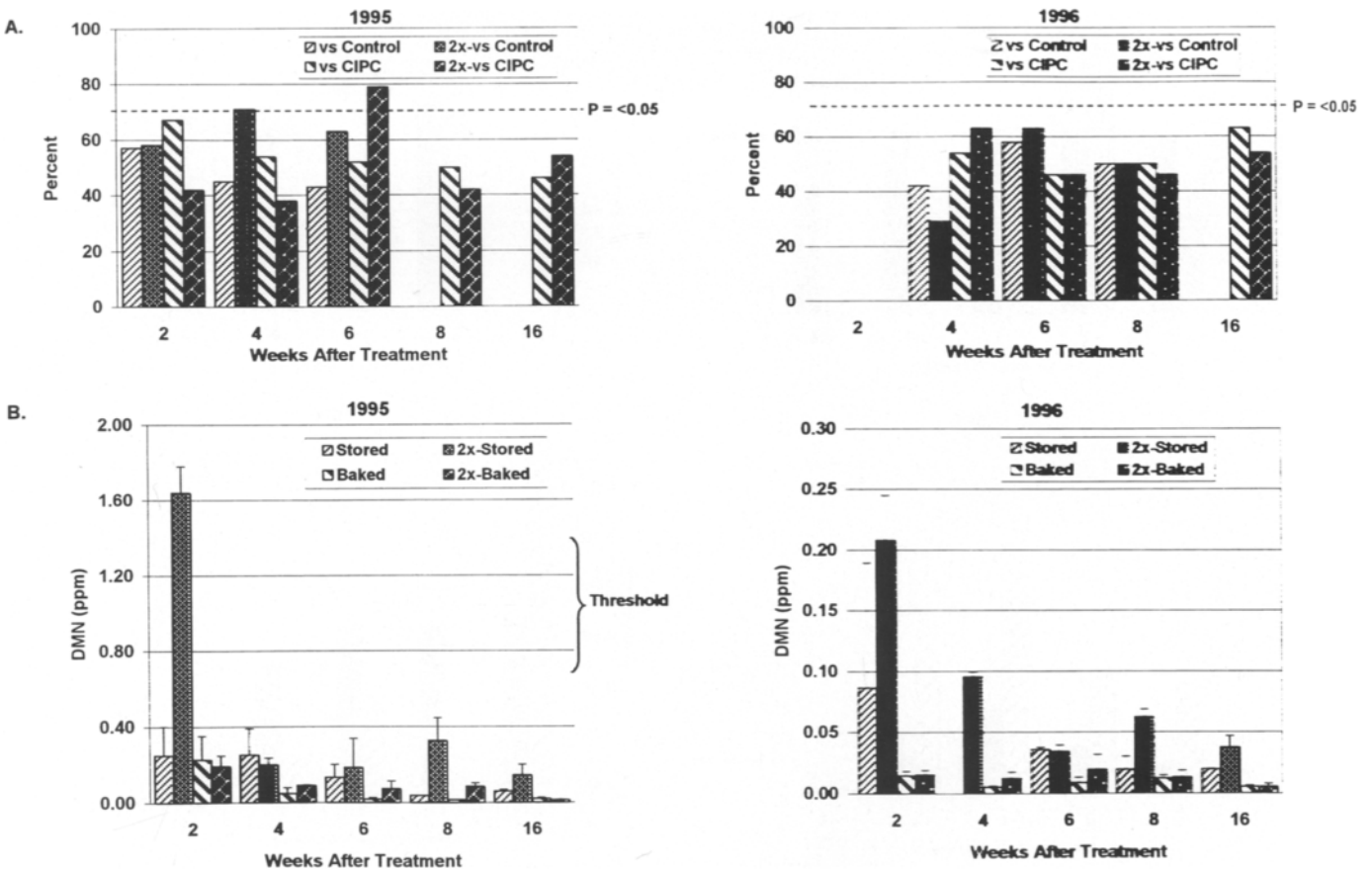

FIGURE 3.
Sensory and analytical results for tubers treated with 40 ppm and 80 ppm 1,4 dimethylnaphthalene (DMN and DMN 2x) by heat aerosol prior to storage at 7 C, 95% R.H. for 16 wk. (A.) Sensory results indicating the proportion of panelists correctly identifying the treated baked potatoes as different from reference baked potatoes. Level of significance is set at P = <0.05. (B.) The concentration of DMN detected in stored and baked potatoes. Brackets indicate the sensory threshold of DMN. Error bars are standard deviation of the mean.

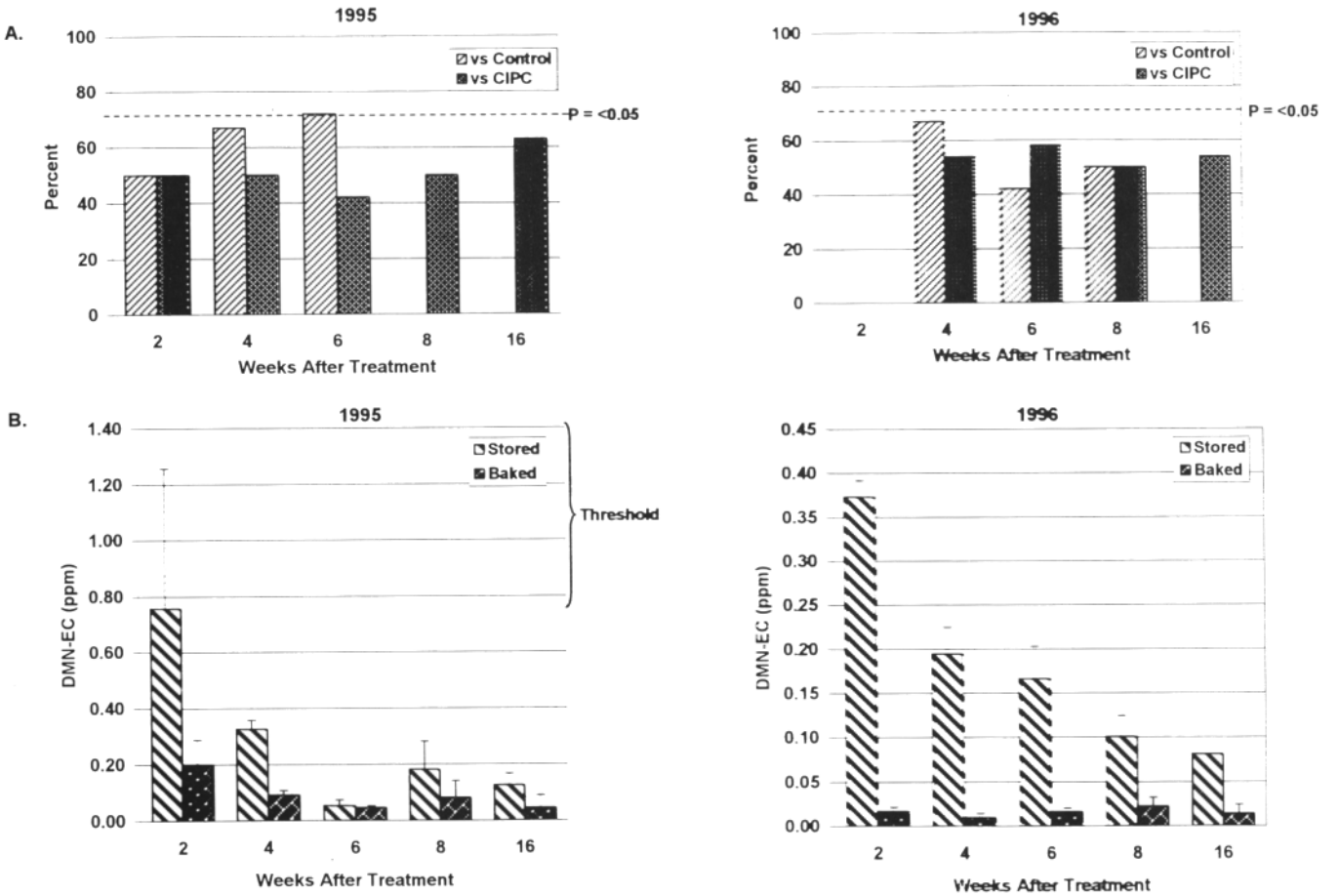

FIGURE 4.
Sensory and analytical results for tubers treated with 40 ppm 1,4 dimethylnaphthalene emulsifiable concentrate (DMN-EC) applied as a spray prior to storage at 7 C, 95% R.H. for 16 wk. (A.) Sensory results indicating the proportion of panelists correctly identifying the treated baked potatoes as different from reference baked potatoes. Level of significance is set at P = <0.05. (B.) The concentration of DMN detected in stored and baked potatoes. Brackets indicate the sensory threshold of DMN. Error bars are standard deviation of the mean.

ing were four to five times lower than the sensory detection threshold of dimethylnaphthalene (Figures 3 and 4). This relationship was noted regardless of the level (40 or 80 ppm) or application method of inhibitor. With a few exceptions, panelists were unable to detect differences in potatoes treated with 1,4-dimethylnaphthalene compared with untreated or CIPC-treated potatoes.

Potatoes treated with salicylaldehyde were judged to be different from the reference potatoes only during the intermediate stages (6-8 wk) of storage, but not during the early or late stages of storage (Figure 5). At the intermediate stage of storage, levels of salicylaldehyde in baked potatoes were below the sensory threshold of salicylaldehyde (Figure 5). However, sprout-inhibiting treatments do alter the metabolism of the potato tuber during storage and subsequently change the content of amino acids, sugars, and other constituents (Daniels-Lake *et al.* 1996; Yang *et al.* 1999). Salicylaldehyde treatment (200 ppm) of stored potatoes resulted in significant increases in reducing sugar content and free amino acids (Yang *et al.* 1999). Thus, changes in flavor characteristics of the potatoes, as a result of treatment with volatile sprout inhibitors, may be attributed to changes in the content of flavor precursors through changes in metabolic activity of the potato tissue in addition to the detection of residual levels of the volatile sprout inhibitors.

In conclusion, certain alternative sprout inhibitors do contribute to detectable sensory differences in potatoes, as compared to untreated or CIPC-treated potatoes. These differences were evident in the potatoes treated with 1,8-cineole or salicylaldehyde, but not 1,4-dimethylnaphthalene. The residual level of sprout inhibitor throughout the 16-wk storage period was

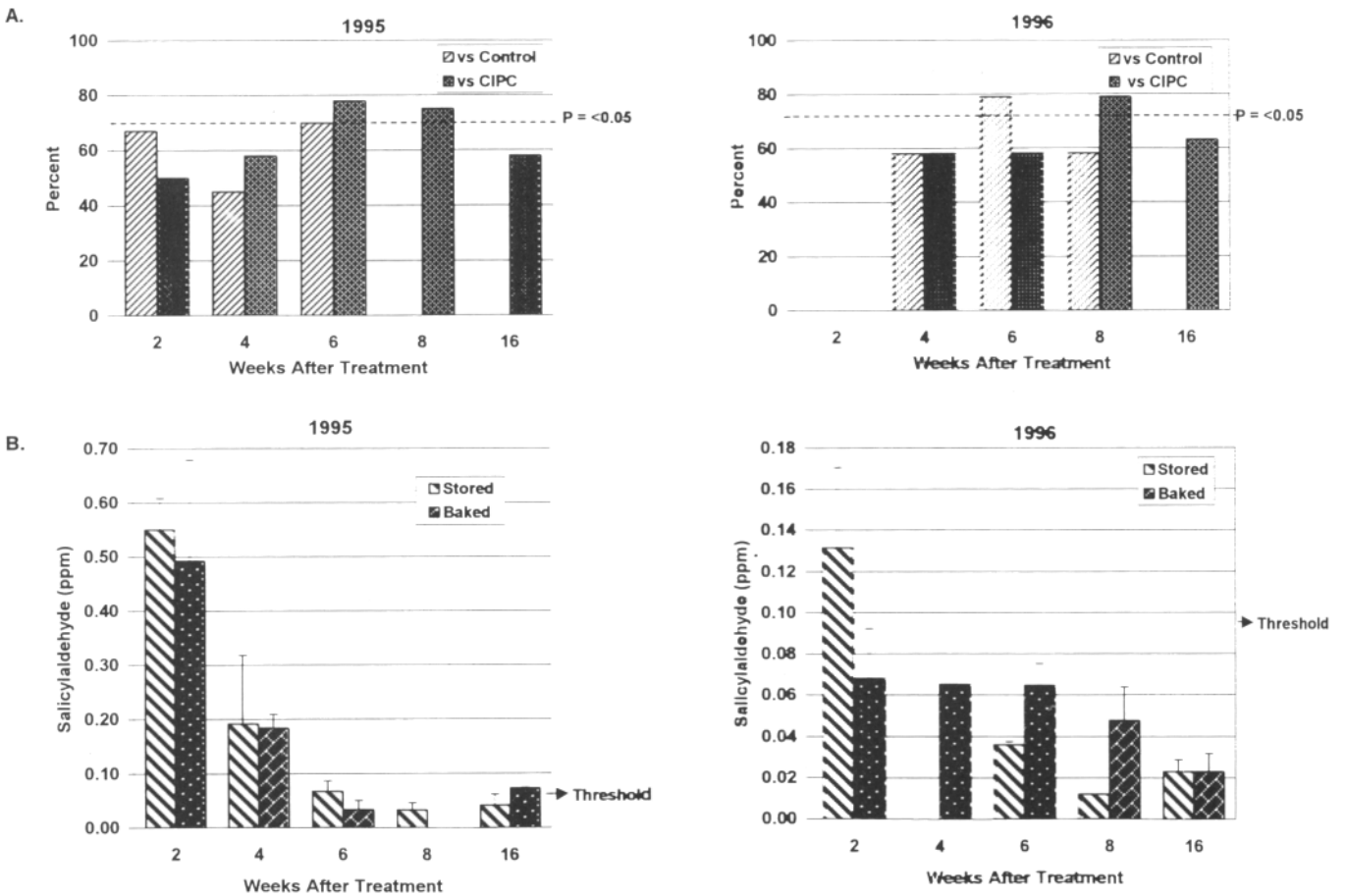

FIGURE 5.
Sensory and analytical results for tubers treated with 200 ppm salicylaldehyde (SAL) by heat aerosol prior to storage at 7 C, 95% R.H. for 16 wk. (A.) Sensory results indicating the proportion of panelists correctly identifying the treated baked potatoes as different from reference baked potatoes. Level of significance is set at P = <0.05. (B.) The concentration of SAL detected in stored and baked potatoes. Arrows indicate the sensory threshold of SAL. Error bars are standard deviation of the mean.

within range of the sensory detection threshold of 1,8-cineole, but not salicylaldehyde or 1,4-dimethylnaphthalene. The effect of these alternative sprout inhibitors on potato metabolism during storage may also contribute to perceived differences in sensory characteristics of treated potatoes. The effect of alternative sprout inhibitors on sensory quality of potatoes and potato products is crucial to selection of successful alternatives to CIPC for sprout inhibition.

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