Effect of Storage Time, Temperature, and Cooking on Isopropyl *N*-(3-Chlorophenyl)carbamate Levels in Potatoes

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Factors affecting the residue levels of the sprout inhibitor isopropyl *N*-(3-chlorophenyl)carbamate (CIPC) in potatoes were studied. Katahdin and Russet Burbank potatoes were dipped in 1% emulsion of CIPC prior to storage. The effects of storage time (1 and 3 months), temperature (5 and 20 °C), and two methods of cooking (boiling and pressure cooking) on CIPC residue in Katahdin and Russet Burbank potatoes were studied. Tubers stored for 3 months retained lower levels of CIPC than those stored for 1 month. Potatoes stored at 5 °C contained significantly ($p < 0.01$) higher levels of CIPC than those stored at 20 °C. Both methods of cooking resulted in significant ($p < 0.01$) losses of CIPC in the peel (periderm). However, the residue of CIPC in the cortex region (under the peel) was significantly ($p < 0.01$) reduced by boiling and significantly ($p < 0.01$) increased by pressure cooking. CIPC retention was significantly ($p < 0.01$) higher in the Katahdin than in the Russet Burbank cultivar.

INTRODUCTION

Sprouting of potatoes during storage can be detrimental to the nutritive value and hence the marketability of the potato. Some of the undesirable changes that occur during sprouting include weight loss, shrinkage, loss of nutritive value, and susceptibility to bruising and enzymatic discoloration. Several methods of sprout inhibition have been employed by the grower and manufacturer such as chemical treatment, irradiation, and low-temperature storage. Commonly used chemical inhibitors include isopropyl *N*-(3-chlorophenyl)carbamate (CIPC), maleic hydrazide (MH), tetrachloronitrobenzene (TCNB), methyl ester of α-naphthalene acid (MENA), and amyl alcohols. CIPC is perhaps the best known form of chemical inhibition of sprouting.

Several studies have been carried out concerning the distribution and changes in CIPC concentration of potatoes during storage. Coxon and Filmer (1984) studied the migration of radiolabeled CIPC into potato tubers and found very little penetration of CIPC beyond the peel even after 6 months of storage. Loss of CIPC by volatilization from the tuber surface was also very small. Corsini et al. (1979) found that significant decreases in CIPC residue of the peel occurred during storage and the minimum level of CIPC in the peel required to inhibit sprouting was about 20 ppm. Majslova and Davidek (1986) reported loss of 70–75% CIPC residue in unpeeled potatoes stored for 2.5 months under forced air circulation and at a temperature of 8 °C and relative humidity of 85%. Peeled potatoes showed a decrease of 9–26% subjected to the same storage conditions and time. These workers also detected a CIPC penetration of 11–21% into the flesh of the tuber.

Little investigation has been done regarding various methods of cooking on the changes of CIPC residues in potatoes. Majslova and Davidek (1986) observed that boiling significantly reduced the CIPC level of the tuber through possible leaching into the cooking water. Peeling the tubers prior to boiling resulted in greater losses of CIPC than found in unpeeled tubers. These results were in agreement with those of Soos and Erdelyi (1976).

There are not enough toxicological data available on the effects of CIPC on animals or humans. Some studies have indicated little or no carcinogenic (WHO/FAO, 1964) and mutagenic effects on eukaryotes (Grutman et al., 1984) of this sprout inhibitor. However, CIPC does have a weak tumor-initiating activity on the skin (WHO/FAO, 1964). Further, CIPC is a derivative of ethylurethane, a well-known carcinogen, and it is not known whether CIPC, once ingested, is converted back to this parent compound.

The objective of this study was to investigate the effect of storage time and temperature as well as two methods of cooking, boiling and pressure cooking, on changes in CIPC residues of Katahdin and Russet Burbank potatoes.

MATERIALS AND METHODS

Katahdin and Russet Burbank potatoes, grown at Cornell Vegetable Research Farm at Freeville, NY, were used in the study. Potatoes were mechanically harvested 20 weeks following planting and stored at 5 °C and 95% relative humidity in the dark until treated with CIPC. Potatoes from two harvests, fall 1989 and fall 1990, were used in this study.

Tubers of size C (3.5–4.0-in. diameter) were randomly selected and dipped in an aqueous emulsion of 1% CIPC for 5 min, air-dried for 20 min, and placed in mesh bags. Control tubers were dipped in water only. The tubers were then stored at two different temperatures: 5 and 20 °C (room temperature). Katahdin tubers were stored for 1 month, while Russet Burbank tubers were stored for up to 3 months.

Two methods of cooking, boiling and pressure cooking, were compared with regard to CIPC retention in the tubers. Boiling was performed by cooking tubers of size C in 2 L of boiling water for 30 min. Pressure cooking was carried out by cooking four tubers of size C in 400 mL of water under 15 psi for 10 min. These methods were chosen since they are among the most common cooking methods used around the world, particularly in India. Further, since these are wet methods of cooking, it is possible that the sprout inhibitor can be translocated to different parts of the tuber during the process of cooking.

Cooked tubers as well as the cooking water were analyzed for CIPC residues; uncooked tubers served as controls. Tubers were cut longitudinally from bud to stem end to obtain uniform sampling form both the apical and basal sections. The peel (periderm) and the cortex (without the periderm) tissues were assayed for CIPC residue.

CIPC Analysis. The HPLC method reported by Weidmann et al. (1980) was used to analyze for CIPC residue. Approximately 15 g of the peel, 25 g of cortex, or 100 mL of the cooking water was used for analysis. Extraction was performed using HPLC grade dichloromethane. The ratio between dichloromethane and water phase for extraction of CIPC from cooking water was 2:1

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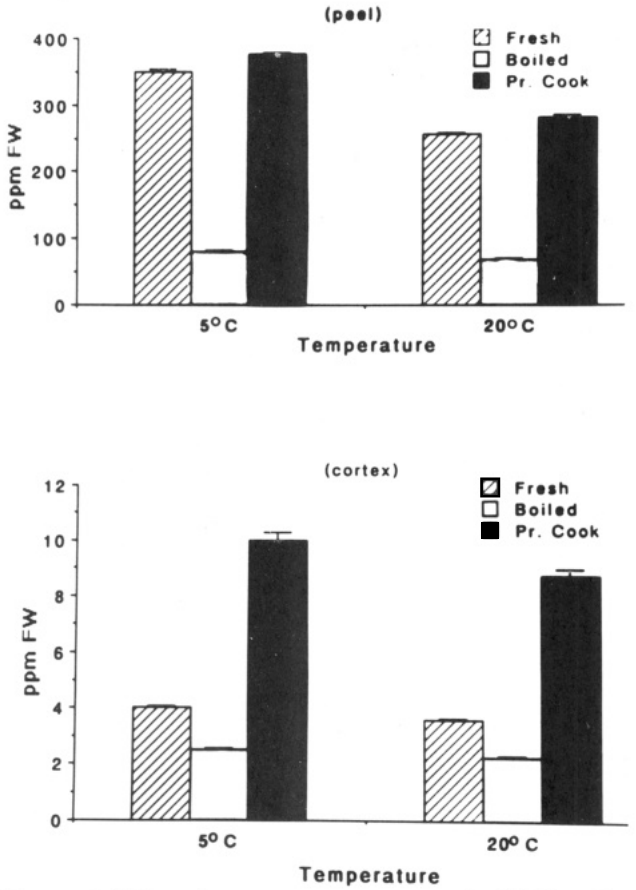

Figure 1. Effect of storage temperature on the CIPC residue levels of peel and cortex tissue of Katahdin tubers. Similar trends were observed for the Russet Burbank cultivar. "FW" denotes fresh weight.

Table I. HPLC Conditions Used for Analysis of CIPC Residue in Potato Tubers

chromatograph	Beckman 421 HPLC
detector	Perkin-Elmer LC-95, UV–visible
integrator	Hewlett-Packard 3390 A
column	25 cm × 4.6 mm i.d. packed with cyanopropyl (CN) base
mobile phase	10% dichloromethane in hexane
flow rate	1.3 mL/min; 500 psi
temperature	70 °C
retention time	6 min from injection
injection volume	20 μL
detector wavelength	UV variable wavelength at 238 nm

(CH_2Cl_2:H_2O). The extract was concentrated using a rotary evaporator maintained at 40 °C. The concentrate was then made up to 5 mL using HPLC grade hexane and centrifuged at 2000 rpm for 10 min, and the supernatant was used for HPLC analysis. Purified CIPC (obtained from Chemical Services, Inc.) was used to prepare the standard. The conditions under which HPLC analysis was performed are shown in Table I.

Statistical Analysis. A completely randomized block design was utilized, and statistical significance was calculated using two-way ANOVA (analysis of variance) as recommended by Steel and Torrie (1980).

RESULTS AND DISCUSSION

Storage temperatures significantly affected the CIPC residue levels of the tubers (Figure 1). Tubers stored at 5 °C contained higher levels of CIPC than those stored at 20 °C. Since CIPC is a volatile compound, volatilization at 20 °C would be greater than at 5 °C and would decrease the CIPC concentration in the tubers. Storage time also showed a substantial effect on the loss of CIPC; tubers

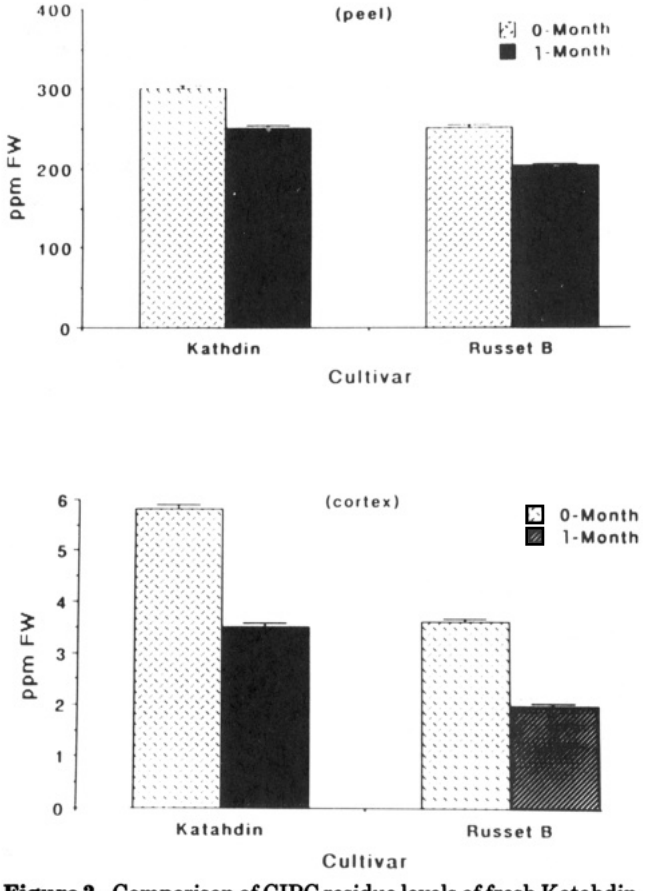

Figure 2. Comparison of CIPC residue levels of fresh Katahdin and Russet Burbank potato tubers. "FW" denotes fresh weight.

stored for 3 months contained lower levels of CIPC than those stored for 1 month. No statistical interaction was observed between the cooking methods and storage temperature.

The CIPC residue of the peel of both Katahdin and Russet Burbank was significantly ($p < 0.01$) reduced by boiling and pressure cooking (Figure 1). The CIPC level of the cortex was significantly ($p < 0.01$) decreased by boiling and increased by pressure cooking. It is possible that the high pressure could have forced some of the residue from the periderm into the cortex. This trend was consistent for potatoes from harvests in two consecutive years. The CIPC residue in the periderm was significantly ($p < 0.01$) higher than in the inner cortex. Periderm CIPC levels exceeded safety levels of 50 ppm recommended by the U.S. Food and Drug Administration (FDA). The CIPC level of the cortex, however, was substantially lower than 50 ppm, with the highest level not exceeding 8.5 ppm. Peeling the tuber prior to consumption would greatly lower the risk of high intakes of CIPC.

Significant varietal differences were also observed. The Katahdin cultivar retained higher levels of CIPC residue than Russet Burbank (Figure 2). Differences in CIPC retention may be attributed to differences in the morphology of the periderm of the two varieties. The Russet Burbank, a cultivar possessing a russet peel, has a rougher surface and greater surface area than the Katahdin, and the greater surface area might facilitate greater volatilization of CIPC. In addition, the rough skin of the Russet Burbank might provide a greater barrier to penetration of CIPC. The inner cortex region of Russet Burbank contained significantly lower levels of CIPC than the cortex of the Kathadin cultivar. It is also possible that uptake of CIPC can be different at the eyes and the skin. Nowak

(1977) reported that CIPC greatly inhibited protein synthesis in the eyes as compared to other parts of the tuber.

Conclusion. The CIPC residue levels remaining in the tuber varied with cooking method, storage temperature, and cultivar. Residue levels were significantly lower in boiled tubers as compared with those that were pressure cooked. The cortex tissue of both varieties cooked by the two different methods without the peel had CIPC levels well below 50 ppm, which is the maximum intake permitted by the FDA. Peel tissue alone, however, contained greater than 50 ppm of CIPC. It is recommended that tubers be cooked in water and the peel removed to greatly reduce the levels of CIPC consumed. Tubers stored at 20 °C retained less CIPC than those stored at 5 °C. Russet Burbank potatoes showed lower CIPC levels than Kathdin potatoes. The rough skin of the Russet Burbank could provide a better barrier to the penetration of CIPC into the potato tuber.

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