

Effect of Lye Peeling Conditions on Sweet Potato Tissue

WILLIAM M. WALTER JR. and WILLIAM E. SCHADEL

ABSTRACT

Heat penetration effects on sweet potato tissue resulting from three lye peeling treatments were evaluated using light and scanning electron microscopy. Heat-mediated starch gelatinization, cell wall separation, chromoplast disruption, and enzymatic discoloration were observed in varying degrees according to the peeling treatment. Starch gelatinization, cell wall separation, and chromoplast disruption decreased in the order: 15-min peel; 30-min pre-soak (water 78–83°C), followed by a 6-min peel; 6-min peel. Discoloration occurred in significant amounts only in the 6-min peel because heat penetration was sufficient to disrupt lacticifer organization but insufficient to inactivate the polyphenol oxidase (PPO) enzyme. The 30-min pre-soak, 6-min peel treatment provided the most attractive finished product.

INTRODUCTION

LYE PEELING at elevated temperatures is widely used as a means of skin removal prior to canning of sweet potatoes. This pre-canning treatment can cause discoloration, which mars the appearance of the finished product. Scott et al. (1944) and Scott and Kattan (1957) have shown that this discoloration occurs when heat penetrates into the tissue causing a temperature increase sufficient to inactivate the respiratory system but insufficient for the inactivation of polyphenoloxidase (PPO). The PPO then reacts with *o*-dihydroxy phenols (DP) to cause the discoloration. These workers suggested that discoloration could be prevented by pre-soaking the roots in a 75–80°C water bath immediately prior to lye peeling. This procedure purportedly raised the internal temperature sufficiently high to inactivate the PPO, thus preventing the PPO-DP reaction. The prolonged lye peeling treatment suggested by Scott et al. (1970) would prevent discoloration by the same mechanism as the pre-soak process of Scott et al. (1944). However, deep peeling would decrease yields because of excessive tissue removal.

None of the previous research has been concerned with changes on a cellular level caused by heat penetration from the peeling medium. The objective of this study was to evaluate the cellular changes resulting from several lye peeling treatments. In particular, development of discoloration, extent of starch gelatinization, cell wall detachment, and chromoplast disruption were studied.

EXPERIMENTAL

'JEWEL' SWEET POTATOES which had been cured for 7 days at 29.5°C and 85% relative humidity were used in this study. After curing, the roots were held at 13°C and 80% relative humidity until used.

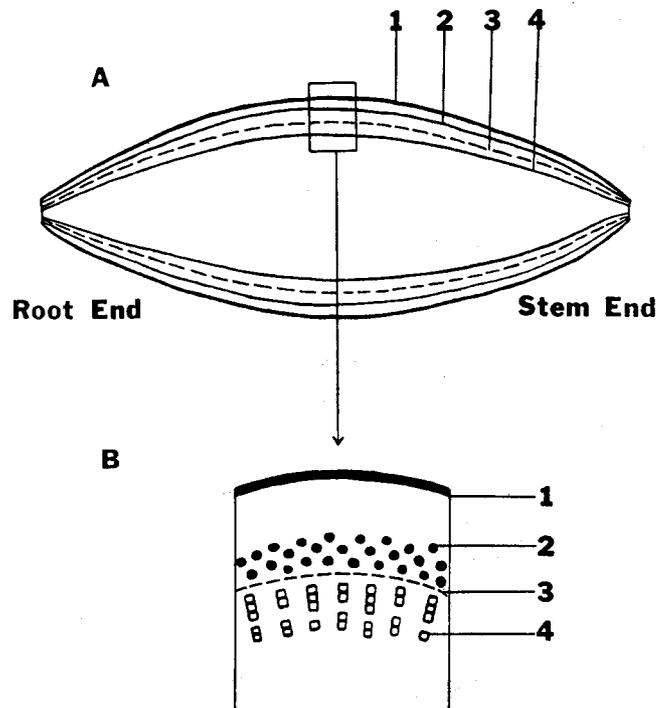
Lye peeling conditions

Five roots (per treatment), approximately 6.5 cm in diameter and 320g in weight, were peeled by immersion in a boiling solution (104°C) of 10% reagent grade NaOH. After the desired lye contact

period elapsed, periderm and outer parenchyma tissue were removed by washing in tap water. The amount of tissue removed was estimated by measuring the distance between the peeled surface and the cambium and subtracting the value from the skin to cambium distance for the unpeeled root. The following peeling treatments were used: (1) 6-min peel (6P), (2) 30-min pre-soak in water at 78–83°C, followed by a 6-min peel (30S), (3) 15-min peel (15P). Five mm cubes of mid-root tissue were removed to a depth of 40 mm from peeled and unpeeled roots for microscopic examination. In addition, entire transverse sections of mid-root tissue were removed immediately after peeling and 1 hr after peeling for unaided visual inspection.

Microscopy

Tissue blocks were fixed in 3% glutaraldehyde, 0.1M sodium cacodylate buffer pH 7.2 at 4°C for 24 hr. For light microscopy, fixed blocks were dehydrated, embedded in glycol methacrylate (GMA; Bennett et al., 1976), and sectioned (5 μ sections) on an ultramicrotome equipped with a glass knife. These sections were examined (transmitted light) with and without histochemical stains and photographed on a Wild M-20 microscope. Distances were measured with a calibrated ocular micrometer. Fixed tissue for scanning electron microscopy (SEM) was immersed overnight in 0.1M sodium cacodylate buffer (pH 7.2, 4°C) containing 5.6% sucrose. Following the buffer rinse, the tissue was dehydrated in a graded water-ethanol series and Freon 13 intermediate fluids. It was then critical-point dried in a Bomar SPC-50EX apparatus using Freon 13 as the transition fluid. The tissue was then gold-coated and observed



Authors Walter and Schadel are with the USDA-SEA-ARS, Southern Region, and North Carolina Agricultural Research Service, Dept. of Food Science, North Carolina State Univ., Raleigh, NC 27650.

Fig. 1—Sweet potato root longitudinal (A) and transverse (B) sections with relative locations of tissues and cell types pertinent to the present study. 1, Periderm; 2, Lacticifer; 3, Cambium; 4, Xylem element.

LYE PEELING OF SWEET POTATOES

at various magnifications at 20 KeV on an ETEC Autoscan microscope. Scanning electron photomicrographs were taken using a Polaroid camera mounted on the cathode ray tube.

Chromoplast disruption and PPO-DP-caused tissue discoloration were evaluated with the light microscope on freshly prepared, quick-frozen samples sectioned (30 μ sections) on a freezing microtome.

Table 1—Evaluation of tissue removal, starch gelatinization, and cell wall detachment caused by lye peeling treatments^a

	Treatment ^c		
	6P	30S	15P
Tissue removed	3– 4 mm	4– 5 mm	5– 6 mm
Starch gelatinization ^b			
Complete	3– 5 mm	3– 6 mm	5– 9 mm
Moderate	6– 8 mm	7–15 mm	10–20 mm
Slight	9–15 mm	16–20 mm	21–25 mm
None	16 mm	21 mm	26 mm
Cell wall detachment ^b			
Severe	3– 5 mm	3– 6 mm	5– 9 mm
Moderate	6–10 mm	7–14 mm	10–15 mm
Slight	11–15 mm	15–17 mm	16–20 mm
None	16 mm	18 mm	21 mm

^a Results tabulated from five roots per treatment.

^b Depth to which changes are noted below peeled surface. For definition of complete, moderate, and slight, see text.

^c 6P = 6 min peel; 30S = 30-min pre-soak, 6-min peel; 15P = 15-min peel.

Histochemistry

GMA-embedded sections were treated with the periodic acid-Schiff stain (cell wall and starch) and with toluidine blue (cell wall) as described by Feder and O'Brien (1968) and were examined with the light microscope. Fresh-frozen sections were treated with 0.1M aqueous catechol for PPO localization (Scott and Kattan, 1957) and the nitrous acid reagent of Reeve (1951) for phenol localization. Fresh, lye-peeled tissue sections from the various treatments were also treated with catechol and nitrous acid reagent for unaided visual examination.

RESULTS & DISCUSSION

FROM THE EXTERIOR to the interior of the root, the tissue and cell types pertinent to the present study include the outermost periderm, laticifer cells exterior to the cambium, the cambium, and xylem elements interior to the cambium (Fig. 1). Approximately 5–6 mm of tissue comprised mainly of starch-poor parenchyma occupies the area between the periderm and cambium. Beginning about 2–3 mm below the periderm, a series of latex-containing cells (laticifers) are located exterior to the cambium. Laticifers are most numerous adjacent to the cambium (ca 25 cells per mm³). Large numbers of radially arranged xylem elements (ca 30 xylem elements per mm³) are located to the interior of the cambium in conjunction with starch-filled storage parenchyma cells. Starch-filled parenchyma cells and other cell types derived from the secondary anomalous cambia are located to the interior of the radially arranged

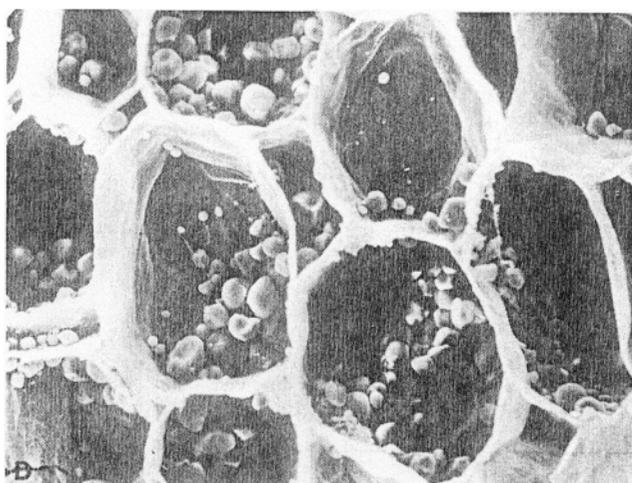
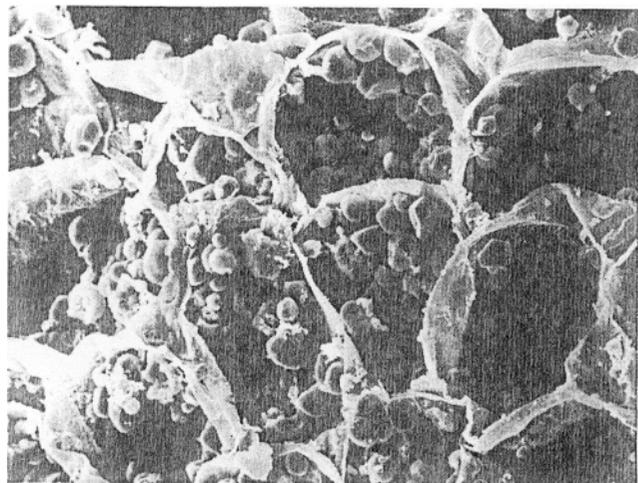
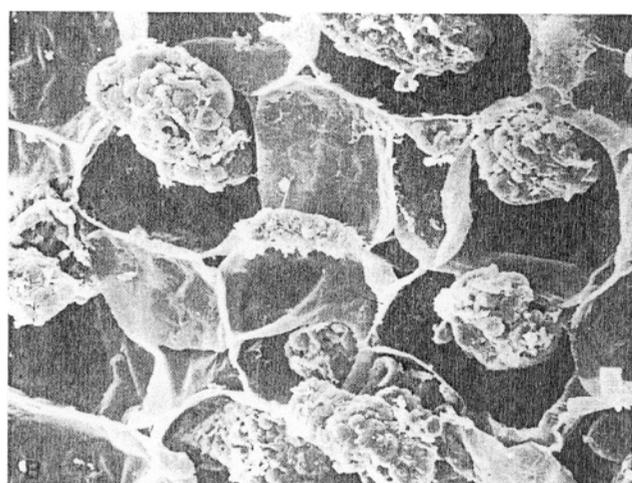
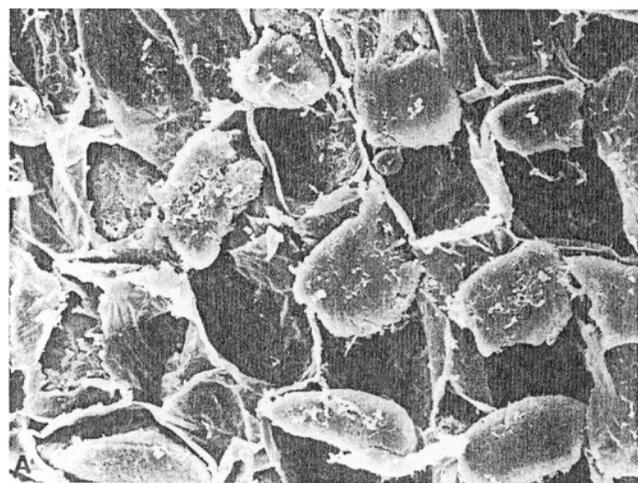


Fig. 2—Scanning electron photomicrographs of starch gelatinization stages in lye-peeled 'Jewel' sweet potatoes: (A) Severe — 435X; (B) Moderate — 420X; (C) Slight — 435X; (D) None — 420X.

xylem elements. Heat penetration from the peeling medium is restricted to the tissue ≤ 2.5 cm from the peeled surface with most of the effect centered in the outer 1.5 cm, which includes parenchyma cells, laticifers, phloem, the cambium, and radially arranged xylem elements (Table 1).

Lye peeling conditions

The 6-min peel (6P) is approximated in some commercial processing operations today. The 30-min pre-soak, 6-min peel (30S) suggested by Scott and Kattan (1957) was used as a process designed to minimize darkening and the 15-min peel (15P) was selected as a deep peel process also devised to minimize darkening.

Tissue removal and heat penetration

Tissue removal increased in the order: $6P < 30S < 15P$ (Table 1). The 15P treatment removed tissue to the depth of and in some cases beneath the cambium, while the other treatments did not reach the cambium. Roots which were peeled beneath the cambium were less attractive because the xylem elements frequently protruded from the surface of the peeled roots and created a rough appearance.

Heat penetration effects are inversely proportional to the distance from the peeled surface. The outward appearance of heat penetration can be observed in a transverse section of a lye peeled root (unaided eye). One observes first an outer yellow concentric ring, then a translucent orange ring and finally an inner opaque orange core of tissue unaffected by heat. Microscopic examination showed that the carotene in the yellow zone was in globular form

and thus had dissolved in cellular lipids. The yellow zone was least in 6P and much greater in the other two treatments (Table 2). The orange zone underlying the yellow zone was characterized (microscopically) by intact chromoplasts, although changes were noted in the appearance of the starch granules. The cumulative heat penetration effects, as indicated by the color change, occur to a depth of 4 mm in the 6P treatment and 11–12 mm in the other treatments.

When peeled root tissue was examined microscopically, heat penetration effects were noted to a greater depth than indicated by the apparent change in color. For microscopic examination, starch gelatinization and cell wall detachment were used as markers of heat penetration (Fig. 2). Starch gelatinization stages are categorized in Table 1. Severe gelatinization (Fig. 3A and 4A) was characterized by the disappearance of individual starch granules and the appear-

Table 2—Effect of heat penetration on the appearance of a transverse section of a peeled root

Treatment	Depth of yellow heat zone ^{a,b}	Depth of orange heat zone ^c
6-min peel (6P)	1 mm	2–4 mm
30-min pre-soak; 6-min peel (30S)	8–9 mm	11–13 mm
15-min peel (15P)	5–6 mm	10–12 mm

^a Depth to which changes are noted below peeled surface.

^b Yellow heat zone appeared as translucent yellow color.

^c Orange heat zone appeared as translucent orange color.

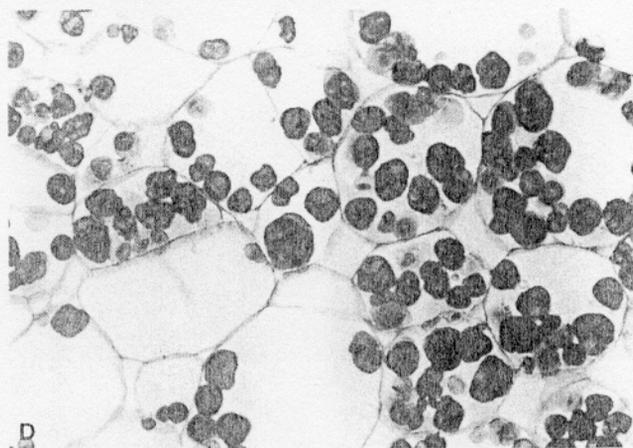
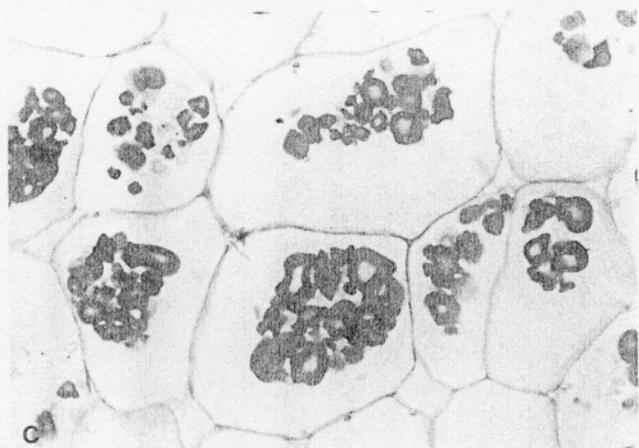
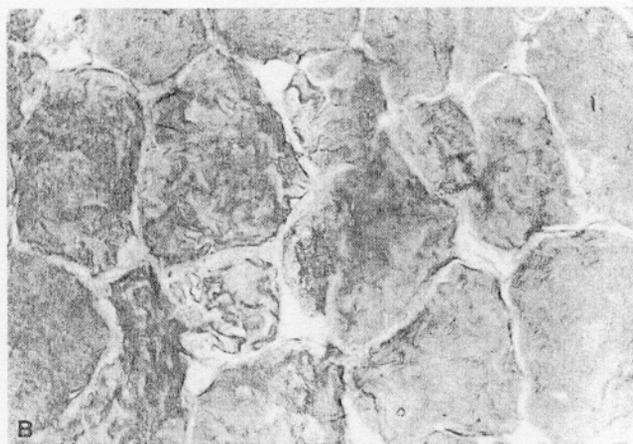
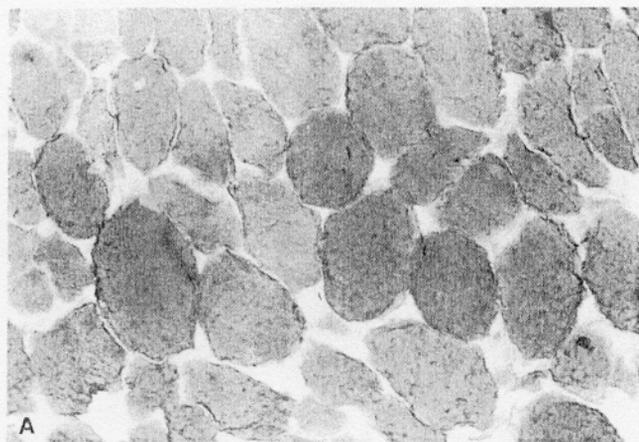


Fig. 3—Light photomicrographs of starch gelatinization stages in lye-peeled 'Jewel' sweet potatoes (GMA sections stained with periodic acid-Schiff reagent): (A) Severe; (B) Moderate; (C) Slight; (D) None. All 400X.

ance of a smooth solid mass of gelatinized starch, which completely filled the cell. Moderate gelatinization (Fig. 3B and 4B) was also characterized by the disappearance of individual granules, but the starch had a reticulated clumped appearance. Slight gelatinization (Fig. 3C and 4C) was observed as a slight clumping and distension of some of the granules. If one observes slightly gelatinized granules under polarized light, some of the granules have lost their birefringence. Normal tissue (Fig. 3D and 4D) is characterized by individual undistended starch granules. Heat penetration effects on starch granules are noted at a maximum of 15 mm in 6P, 20 mm in 30S, and 25 mm in 15P.

Heat effects on cell walls were not as visually striking as on starch granules. The maximum effect on cell walls occurred in the outer parenchymatous tissue immediately adjacent to the peeled surface. Damage occurred in the form of cell wall to cell wall detachment in the tissue to a depth of 3–9 mm depending upon the treatment (Table 1). Severe cell wall detachment (Fig. 5A) was characterized by almost complete detachment. Moderate damage (Fig. 5B) involved some cell wall detachment scattered throughout the tissue section and slight detachment involved only the rare occurrence of detached walls (Fig. 5C). Normal tissue (Fig. 4D and 5D) is provided for comparison. Cell wall damage was detected to a depth of 15 mm in 6P, 17 mm in 30S, and 20 mm in 15P. As with starch granule disruption, severe to moderate cell wall detachment occurred much deeper in the tissue of 30S and 15P treatments than in the 6P treatment (Table 1).

Discoloration

Of concern to the processor is a heat-induced discoloration zone (Fig. 5B), which occurs in the cambial area after lye peeling. This discoloration, which can become quite pronounced within 10–15 min after the root is removed from the peeling bath, has been shown to result from the PPO-DP reaction (Scott et al., 1944; Scott and Kattan, 1957). Walter and Giesbrecht (1982) have demonstrated that in lye peeled roots, DP levels are decreased by the peeling treatment and that treatment which causes the most severe darkening (6P) also has the largest decrease in DP levels (1 hr post peeling) indicating that DP are being destroyed while discoloration is increasing.

Scott and Kattan (1957) proposed that discoloration resulted when the heat penetration was not sufficient to destroy PPO but sufficient to disrupt cellular respiration. However, any such theory must explain where the substrate (DP) is located and how the PPO-DP interaction occurs. Recent work (Schadel and Walter, 1981) in this laboratory has indicated that significant concentrations of PPO and DP are located adjacent to the periderm and in the laticifers. In addition, DP are also found in the parenchyma cells contiguous to xylem elements. No PPO was localized in these cells.

In the lye-peeling process, the enzyme (PPO) and substrate (DP) near the periderm are removed and thus cannot contribute to discoloration. Since PPO and DP are both present in the laticifers, discoloration may result from a heat-induced breakdown of the laticifers. If the laticifers'

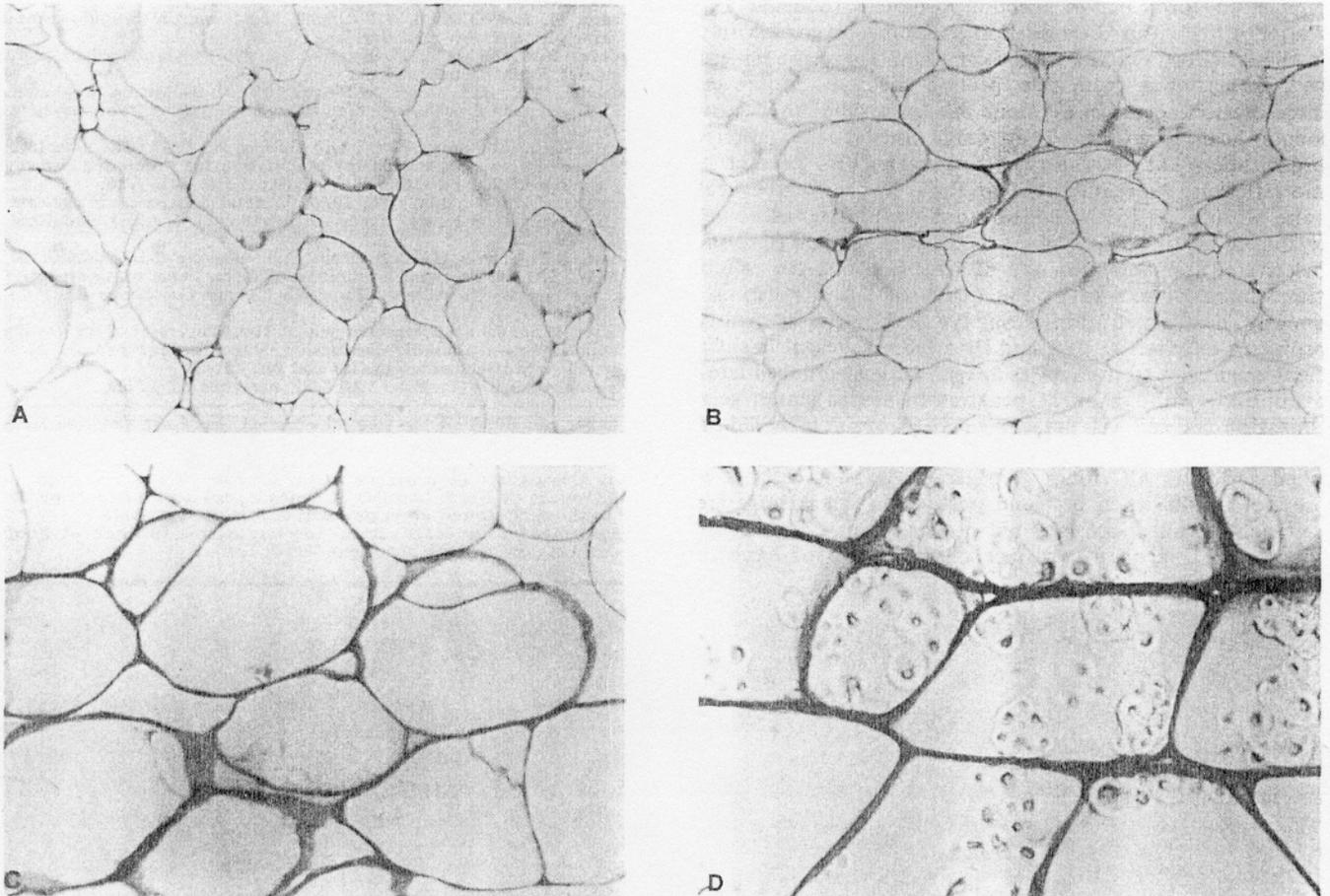


Fig. 4—Light photomicrographs of cell wall to cell wall detachment in lye-peeled 'Jewel' sweet potatoes (GMA sections stained with toluidine blue): (A) Severe; (B) Moderate; (C) Slight; (D) None. All 400X.

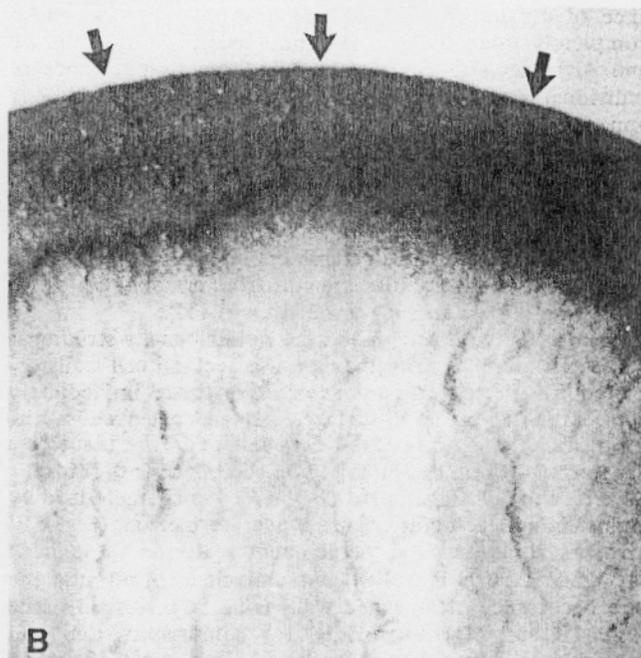
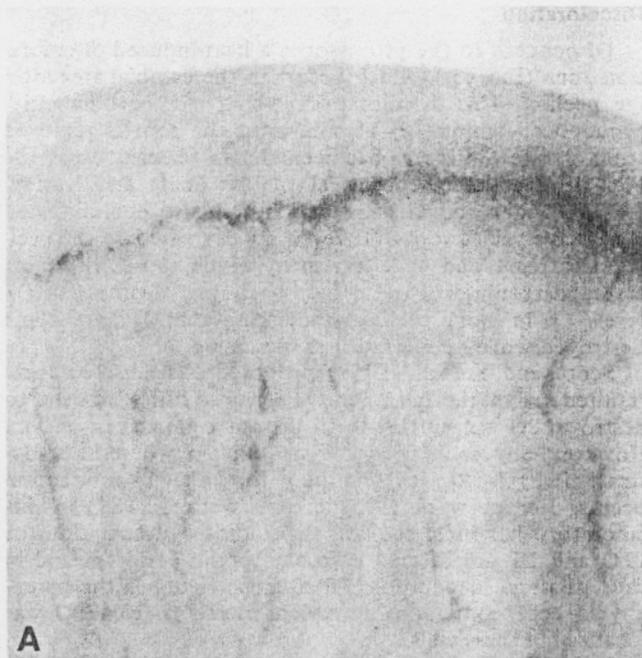


Fig. 5—Sweet potato root transverse section (A) immediately after 6-min lye peeling — 5X; (B) 1 hr after 6-Min lye peeling (arrows indicate discolored latex) — 5X.

cellular organization and compartmentalization are disrupted, the PPO and DP interact. This subsequently leads to the discoloration of the latex by reactive quinones that polymerize to form brown reaction products (Schadel and Walter, 1981). This discoloration phenomenon occurs only in the laticifers, external to the cambium due to the limited heat penetration from the peeling medium. Moreover, discoloration occurs in 6P alone because in the other treatments heat penetration not only disrupts the laticifer organization but also heat inactivates the PPO present in the laticifers. As is indicated in Table 2, the yellow heat zone of 30S and 15P extends beyond the laticifer-cambium region, indicating that this tissue has been cooked (enzyme inactivated). However, in the 6P treated roots, the yellow zone does not extend to the depth of laticifers. Consequently, heat penetration during lye peeling causes quality problems only where PPO and DP are both present in sufficient quantities to interact as a result of heat-induced latex disruption. Although heat penetration causes starch gelatinization and cell wall detachment to a considerable depth, these changes do not detract from the quality of the finished product. All things considered, the most attractive product results when pre- and post-peeling treatments are sufficient to inactivate PPO but not severe enough to cause the rough, unattractive surface characteristic of exposed xylem elements.

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