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Effect of Lye Peeling Conditions on Phenolic Destruction, Starch Hydrolysis, and Carotene Loss in Sweet Potatoes

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ABSTRACT

'Jewel' sweet potatoes were peeled in a boiling, 10% NaOH solution using the following treatments: (1) 6-min peel (6P); (2) 20-min pre-soak in water (55°C) followed by a 6-min peel (20S); (3) 30-min pre-soak in water (80°C) followed by a 6-min peel (30S); (4) 15-min peel (15P). Tissue from the heat-affected area was excised and analyzed for *o*-dihydroxyphenols (DP) and carotene destruction and sugar formation. The data showed that roots peeled by 6P or 20S treatments could discolor as a result of the PPO-DP reaction. Discoloration would not be found in 15P and 30S because both treatments are vigorous enough to inactivate the PPO system. Amylolytic enzymes are inactivated by all treatments except 6P. No carotenoid destruction was detected.

INTRODUCTION

LYE PEELING of sweet potatoes can cause discoloration of the cambial region and result in an unattractive finished product. This discoloration or darkening has been attributed to the reaction between polyphenoloxidase (PPO) and *o*-dihydroxyphenols (DP) (Scott and Kattan, 1957). It has been shown that during the normal 6-min peeling process, the heat from the lye bath penetrates into the tissue causing laticifer disorganization (Walter and Schadel, 1982). The laticifer cells, which contain large amounts of DP and high PPO activity, are organized in such a way that the enzyme and substrate are separated. When heat penetration is sufficient to disrupt the laticifers but insuffient to inactivate PPO, the darkening reaction occurs.

Walter and Schadel (1982) demonstrated that when lye peeling conditions were selected to maximize heat penetration in the lacticifer region (cambial area), no darkening was observed. For example, using either a 15-min lye peel or a presoak in hot water prior to a 6-min peel, no discoloration was observed 1 hr after peeling, indicating that the PPO enzyme system had been heat-inactivated. On the other hand, when a 6-min lye peeling treatment was used, discoloration, although not evident immediately after removal from the lye bath, became quite pronounced after 1 hr.

The purpose of this study was to examine the effect of the lye peeling treatments described by Walter and Schadel (1982) on the level of DP (PPO substrate) in the heat-affected tissue. In addition, changes in reducing sugar and carotene levels were also measured to determine if amylolytic or carotene destroying enzymes were activated or destroyed by the lye peeling treatments.

MATERIAL & METHODS

'JEWEL' sweet potatoes were harvested, cured and stored using recommended horticultural practices (Covington et al., 1976). Roots approximately 5–6.5 cm in diameter and 280–320g were selected for the study.

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Lye peeling

Four lye peeling treatments were used. In all cases the lye bath contained boiling (104°C), 10% aqueous sodium hydroxide. The treatments were as follows: (1) 6-min lye peel (6P); (2) 15-min lye peel (15P); (3) 20-min pre-soak in water at 55°C, followed by a 6-min lye peel (20S); (4) 30-min pre-soak in water at 80°C, followed by a 6-min lye peel (30S).

Each root was held in the bath (lye or pre-soak) so that its long axis was half immersed. The upper half served as the no-heat or control treatment. After peeling, the root was washed with tap water to remove lye-contacted tissue, halved at mid-root (short axis) and sliced into 5 mm cross sections. Half of the sections were set aside as 1 hr samples. The remainder served as zero time samples. The amount of tissue removed from zero time samples by lye-peeling was determined (Walter and Schadel, 1982) and that amount was removed from the half of the slice that received no heat treatment. Tissue from the lye peeled half which had been affected by heat was observed as a yellow to orange zone (Walter and Schadel, 1982). This tissue was excised and a section equal in size was removed from the control half of the slice. The two tissue samples were designated as lye peeled and control, respectively. The remainder of the zero time slices were treated in the same way. Tissue from each treatment (lye peeled or control) was combined, sliced into 3 mm cubes, weighed, and homogenized in appropriate solvents. After 1 hr had elapsed, the other half of the original tissue sections were handled in the same manner as the zero time samples. These were designated as 1 hr lye peeled and control samples. Thus, each root served as its own control. This was necessary because of the high root to root variability in phenol levels (Walter and Purcell, 1980). Tissue from control and lye peeled portions of each slice were carefully matched because of the unequal anatomical distribution of the phenols (Walter and Schadel, 1981). From each root (replicate), four samples were obtained; zero time control and lye peeled, and 1 hr control and lye peeled.

Analyses

Phenolics. A 4–6g sample (nearest 0.001g) of the diced tissue was mixed with 35 ml of 95% ethanol and homogenized (Tekmar SDT Tissumizer) for 1 min. The slurry was quantitatively transferred to a 50-ml volumetric flask, stoppered, and stored in the dark at room temperature for 1 wk. Immediately prior to analysis, each flask was diluted to volume with ethanol and mixed. A 2–3 ml aliquot was removed, the liquid evaporated, and 1 ml of coumarin (40 μg per ml) was added as an internal standard. The solution was passed through a C-18 clean-up column prior to analysis (Walter et al., 1979). Individual phenolics were separated on a Waters ALC/GPC-204 instrument using a two-chambered gradient device containing methanol and 0.033M phosphate (pH 3.1) (Walter and Schadel, 1981). A μ-Bondapak C-18 column (3.9 x 300 mm) was used for the separation, the flow rate was 1.5 ml/min, and the column effluent was monitored with a Waters model 440 detector operating at 313 nm. Quantification of phenolics was accomplished by electronic integration of the peak areas, followed by application of the internal standard method to the peak areas (Walter et al., 1979).

Sugars. A 2.00g sample of diced tissue was homogenized with 30 ml of boiling 80% aqueous ethanol, transferred to a 50 ml volumetric flask and held for 1 wk at room temperature. Before analysis the sample was diluted to volume and mixed. Suitable aliquots were diluted with water and the reducing sugar measured (Hodge, 1964) as maltose.

Carotenoids. A 2.00g sample of the diced tissue was mixed with 4g of Na_2SO_4 (anhydrous) and homogenized with 30 ml of acetone-hexane (9:1, v:v), transferred to a 50 ml volumetric flask, diluted to volume and mixed. After the solution cleared (about 2 hr), the absorbance at 453 nm was measured on a Cary model 15 spectro-

photometer. The absorbance values were used directly to calculate changes in carotenoid content.

Statistics

The data were transformed into percent change form (destroyed for phenolics and increased for sugars) and analyzed by the analysis of variance (ANOVA) procedure. Because unequal numbers of roots were peeled by each treatment, the approximate least significant differences were calculated using the mean square error term and the smallest number of observation (n = 8) among the treatments (Steele and Torrie, 1960).

RESULTS & DISCUSSION

LYE PEELING TREATMENTS used in this study were the same as described by Walter and Schadel (1982) except that an additional, milder pre-soak treatment (20S) than the 30S was included in the phenol destruction study. It was thought that the 20S treatment would accomplish PPO inactivation with less tissue damage than the 30S treatment. This did not turn out to be the case.

Phenolics

A typical HPLC chromatograph of the phenolic extract for lye peeled tissue is shown in Fig. 1. The series of peaks from 2.5–12.5 min appear only in the lye peeled tissue. These peaks were quantitated in the same way as the others and statistically analyzed. Similar amounts were formed in all four lye treatment processes, and the amounts had not increased after 1 hr. Since phenols were destroyed at different rates in the different processes and phenol destruction in some treatments increased after 1 hr, it was concluded that these early peaks were not linked to phenol destruction and thus were not further studied.

Sweet potato phenolics have been identified (Walter et al., 1979) as caffeoyl esters. Chlorogenic acid and isochlorogenic acid are the major phenolics. A small amount of an isomer of chlorogenic acid is also present. Chlorogenic acid isomers (CA) contain one caffeic acid molecule esterified to one quinic acid molecule. Isochlorogenic acid (ISO) contains two caffeoyl residues per quinic acid moiety. Although ISO was originally thought to be one compound, more sensitive analytical methods have shown that there are three isomers (Sondheimer, 1964).

Phenolic levels of roots subjected to the same treatment were found to be highly variable due to both root to root differences and also to differences in the relative amounts of the mono and di-caffeoyl isomers. Consequently data transformations were performed prior to statistical evaluation of the data. First the amounts of mono-caffeoyls (CA) and di-caffeoyls (ISO) were determined from the quantitative data for the individual phenolic isomers. Addition of CA and ISO values gave the total amount (TOT) of phenolics. The data consisted of values for CA, ISO and TOT for each of the four samples obtained from each replicate (zero time control and lye peeled, and 1 hr control and lye peeled). The data were then transformed into percent destroyed as follows:

$$\% \text{ Destroyed} = \frac{\text{Control CA conc} - \text{CA conc after lye peeling}}{\text{Control Ca conc}} \times 100$$

This transformation was repeated for ISO and TOT values. The transformed data were analyzed for statistically significant differences.

Statistical analysis of pooled percent destroyed data (data not shown) from the four peeling treatments showed that CHL and ISO isomers were destroyed to the same extent, indicating that neither mono- nor di-isomers are preferentially attacked. The losses for zero time were 11.2% for CHL and 17.8% for ISO. After 1 hr, destruction had increased to 49.1% and 45.0% for CHL and ISO, respectively.

Using the transformations described above, considerable within-treatment variation was observed. The LSD values ranged from 26.3 to 23.0% destruction (Table 1). This variability was most likely due to large root to root differences in phenolic content as well as our inability to obtain anatomically identical tissue sections from the control and peeled roots. Slight variations in excising tissue from the same anatomical area of both sections would result in significant differences in phenolic levels because of the location-dependence of sweet potato phenolics (Walter and Schadel, 1981). The data in Table 1 indicate that only in the 30S treatment is total phenol destruction less than phenol destruction in the 6P treatment for zero time samples. After 1 hr, 30S and 15P exhibit less destruction than 6P. The 20S treatment is intermediate between the two extremes.

Walter and Schadel (1982) reported that only the 6P samples formed the cambial discoloration zone and that discoloration occurred within 1 hr after peeling. The quantitative data confirm these observations. The zero time samples show that all treatments cause a loss of phenolics. After 1 hr, 6P shows the greatest phenol destruction, indicating that the PPO enzyme system is still very active. Further evidence of the treatment effect on PPO activity is provided in Table 2. This table indicates that in 6P and 20S there is significant increase in phenolic destruction

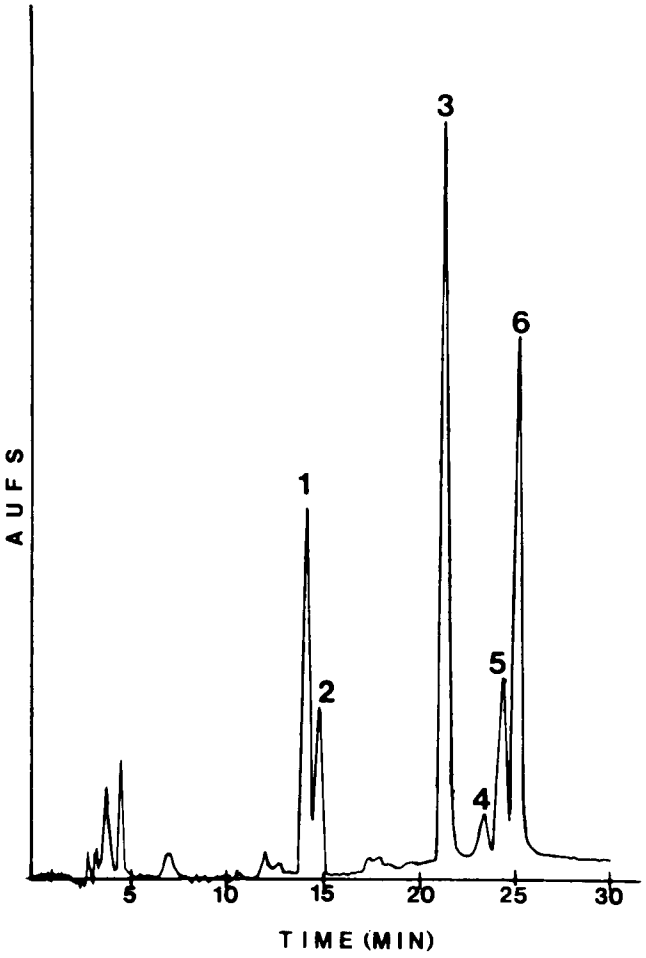

Fig. 1—HPLC chromatogram of phenolics from a 6-min lye peel. Peak 1 was chlorogenic acid; peak 2, chlorogenic acid isomers; peak 3, coumarin (internal standard); peaks 4–6, isochlorogenic acid.

between zero time and 1 hr. This reinforces the evidence which suggests the PPO system is much more active in the 6P sample than in 15P and 30S. Although 20S was not included in the study of Walter and Schadel (1982), the data indicate that discoloration would occur as a result of this treatment.

Sugars and carotenoids

The sugar content of tissue, affected by heat severe enough to cause starch gelatinization, should increase due to amylolytic enzymes present in sweet potato (Walter et al., 1975). Microscopic examination (polarized light) of the tissue encompassed by the yellow to orange heat zone (Walter and Schadel, 1981b) indicated that starch gelatinization had occurred in this region. Sugar analysis of this tissue indicated that significant increases in sugar did occur in all treatments, suggesting that amylolytic enzymes were active initially. The raw data were transformed into percent increase before statistical analysis. There were no significant differences in sugar content among the peeling treatments at zero time. After 1 hr, the 6P treatment showed a greater sugar increase than the other treatments (Table 3), indicating that like PPO, amylolytic enzymes were still active.

It was not known if carotenoid pigments, mainly β-carotene (pro-vitamin A), are adversely affected by heat-caused cellular disruption. Consequently, carotenoid analyses were performed on the same material used for sugar analyses. Each lye peeling treatment was replicated six times (one replication per root). In the yellow heat zone (Walter and Schadel, 1982), carotenoid chromoplasts disappeared and the carotenoids were distributed in droplets, indicating that cellular organization had been disrupted. However, chromoplasts in the orange heat zone were intact. Analysis of the heat-affected tissue (both orange and yellow zones) indicated that more carotenoids (12.37%; $LSD_{.05}$ 9.57%) were present in the 1 hr 15P treatment than in the unheated control. This was most likely due to easier extraction from the cooked tissue than from the control samples. However, there was no statistically significant destruction of carotenoids in any of the four peeling treatments.

Table 1—Percent destruction of phenolics caused by lye peeling treatments

Treatment	N[a]	CHL 0 Time	CHL 1 hr	ISO 0 Time	ISO 1 Hr	Total 0 Time	Total 1 Hr
6-min peel (6P)	8	27.7	71.4	31.1	65.2	29.5	68.3
15-min peel (15P)	8	18.3	42.4	15.8	31.3	16.9	36.5
20-min pre-soak, 6-min peel (20S)	9	4.6	58.4	13.1	59.3	11.3	59.4
30-min pre-soak, 6-min peel (30S)	17	(−5.8)[b]	24.0	11.3	24.1	3.0	22.7
$LSD_{.05}$		26.3		24.5		23.0	

[a] N is the number of roots (replicates) used per treatment.
[b] A negative number indicates formation rather than destruction.

Table 2—Increase in total phenolic destruction[a] between the 0 time and 1 hr samples

Treatment	Total phenolics
6-min peel (6P)	39.0[b]
15-min peel (15P)	19.6
20-min pre-soak; 6-min peel (20S)	48.1[b]
30-min pre-soak; 6-min peel (30S)	19.7

[a] Destruction = 1 hr destruction — 0 time destruction (from Table 1).
[b] Denotes statistically significant increase ($P<0.05$).

Table 3—Percent increase in sugar caused by lye peeling treatments

Treatment	N[a]	Sugar 0 Time	Sugar 1 Hr
6-min peel (6P)	6	70.7	96.4
15-min peel (15P)	6	54.1	51.9
30-min pre-soak; 6-min peel (30S)	6	48.6	53.9
$LSD_{.05}$		36.2	

[a] N is the number of roots used in each treatment.

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