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Peel and Trim Yield and Quality of Beets and Sweet Potatoes Peeled with Superheated Steam, Saturated Steam, and Lye[1]

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Abstract. **Roots of sweet potato [*Ipomoea batatas* (L.) Lam.] and beet (*Beta vulgaris* L.) peeled with superheated steam, had higher peel and trim yields than did those peeled with saturated steam at the same pressure. Product recovery was greater with all steam-peeling methods than with caustic peeling. Direct injection of cold water into the partially pressurized steam atmosphere of the peeler also increased product recovery. Better color retention in processed beets was obtained from steam-peeled roots than from caustic-peeled roots.**

Root crops may be peeled by the use of heat, chemicals, or abrasive action. The method of peeling affects the yield and quality of the finished product, the labor requirements for subsequent inspections, the amount of waste, and the cost of waste disposal. Under ideal conditions, peeling should remove only a very thin outer layer of the raw product, leave no eyelets or blemishes to be removed by hand-trimming, and leave the newly exposed surface of the root unchanged by contact with chemicals or heat.

Among the more difficult root crops to peel while maintaining quality are sweet potatoes and beets. Beets are quite susceptible to pigment leaching and to enzymatic darkening on cut surfaces. Most of the common commercial peeling methods involve steam blanching to prevent enzymatic darkening, followed by peeling either in lye peelers or steam peelers (4). Since betanin, the red pigment of beets, is water-soluble, operations such as peeling, blanching, cutting, and washing should be accomplished rapidly with a minimum use of water. An ideal peeling operation would thus have a high product recovery with little or no pigment leaching or thermal destruction.

Successful peeling of sweet potatoes requires sufficient heat to blanch the outer tissues and protect the product from discoloration, but this heating must be of a short duration to avoid high peeling losses and the breakdown of surface tissues which renders further hand-operations difficult (5). Present commercial peeling of sweet potatoes is generally accomplished with lye

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immersion followed by spray washing, although some processors are using steam peeling. Either method produces a satisfactory product for further processing; however, peeling depths are much greater than the optimal levels described by Harris and Barber (2).

Steam-peeling processes for peeling produce have been described by Edit and McArthur (1) and by Huxsol and Smith (3). Harris and Barber (2) showed that the depth and uniformity of the peel depends upon the steam pressure used and the rapidity of diffusion of steam among the produce being peeled. Smith et al. (5) reported that rapid heating to peeling temperature and flash cooling by injection of cold water into the peeling chamber resulted in improved yields and quality of peeled sweet potatoes.

This study was undertaken to examine the efficiency of various peeling methods on root crops, and to compare the peel and trim yields from roots peeled by superheated steam with those peeled by more conventional methods.

Material and Methods

Sweet potatoes. Roots of the 'Red Jewel' sweet potato grown at the Horticulture Unit of the Auburn University Experiment Station Farm, Shorter, Ala. were used in this study. Roots were cured for 8 days at 29.5°C and 95% relative humidity and all roots were held in storage at 13° and 95% relative humidity until processed. Before peeling, the roots were graded into groups having diameters of 2.5 to 3.5 cm; 3.5 to 5.5 cm; 5.5 to 6.5 cm; and > 6.5 cm. These roots were washed and sorted immediately before peeling and defective roots were removed to minimize variation due to cut surfaces and other damage.

Beets. All tests were conducted using 'Asgrow Wonder' beets grown on the North Alabama Horticulture Substation, Cullman, Ala. Roots were graded to ensure a mean diameter of 6.0 cm and a mean weight of 130 g, were held at 0°C, and were processed within 5 days of harvest.

Steam peeling. A tumbling batch-type laboratory pilot model steam peeler of 1/4 bu. (8.8 liter) capacity (Fig. 1) was modified to accept either saturated or superheated steam (371°C) at 7 kg/cm^2 (100 psi). Steam was fed into the peeler through a 1/2-inch (1.8 cm) manifold at the swivel joint and entered two 1/4-inch (0.9 cm) steam diffusers, which distributed the steam along the length and on opposite sides of the rotating peeler. The diffusers along with the rotation of the peeler ensured rapid and uniform distribution of steam and heating of the produce to be peeled. Another design feature provided for direct injection of cold water at 20° into the peeling chamber through the steam diffuser system. This distributed water among the produce, accelerating cooling, thus reducing the pressure in the chamber by condensing the remaining steam.

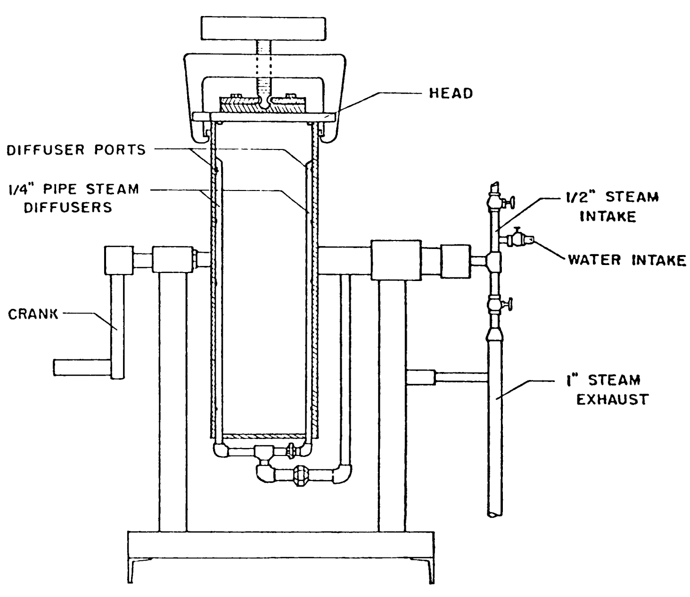

Fig. 1. Steam-peeling apparatus.

During operation, the peeler was preheated and then charged with 10 roots in an atmosphere of steam. The peeling chamber was sealed and steam was introduced into the transversely rotating peeler for 50 sec for beets and 70 sec for sweet potatoes when saturated steam was used and 45 sec and 60 seconds, respectively, when superheated steam was used. At the end of this heating period, the steam inlet was closed and the exhaust was opened until the chamber pressure fell to 1.76 kg/cm^2 (25 psi). The exhaust was then closed and cold water at a line pressure of 4.57 kg/cm^2 (65 psi) was injected into the peeling chamber for 5 sec. The roots were then discharged and washed in a rod washer. Data in each case were collected from 10 replicated peeling trials for each variable.

Chemical peeling. All chemical peeling tests utilized a ferris wheel-type caustic peeler. Optimal peeling of sweet potatoes was accomplished with a 10% w/w solution of NaOH and an exposure time of 5 min at 106°C, while 2-1/2 min in a 10% solution at this temperature was optimal for beets. The wash process following peeling was the same as used with other treatments.

Evaluation. The total peel and trim yield was determined by weighing the roots before and after peeling. Surface color was determined using a Hunter Color Difference Meter standardized to a red standard where L = 68.7, a = 23.0, and b = 9.4. All color readings were taken about 10 min after peeling. Total solids were determined by drying 10-g samples to a constant weight in a vacuum oven at 65°C. The depth of heat penetration was measured by direct measurement of the translucent zone in the peeled roots. The heat ring was measured as the width of the dark ring that formed within 30 min at the inner boundry of heat penetration.

Processed beets. Experimental packs of canned sliced beets and whole, pickled beets were processed to evaluate the quality of the processed product after each peeling method. The pickled beets were given a short preheating treatment (10 min at 96°C) in the pickling syrup, packed in jars where final processing (100° for 17 min) was done after spice and syrup were added. This method results in good flavor, texture, color, and a higher ratio of beets to syrup than cold pack methods.

The sliced beet pack consisted of beets sliced 7 mm thick after peeling, packed into pint jars, and covered with a light brine at 94°C. The jars were exhausted and sealed before retorting at 121° for 18 min.

Results and Discussion

Superheated steam used in conjunction with direct injection of cold water into the steam atmosphere of a steam-peeling chamber resulted in a higher recovery of peeled roots than any of the other peeling methods for sweet potatoes and beets (Tables 1, 2). This peeling method is characterized by rapid transfer of heat to the surface of the produce to be peeled, followed by a very rapid release of pressure and cessation of heat treatment. When peeling with saturated steam, the roots are exposed to lower temperatures and maximum peeling-chamber pressure is reached more slowly, requiring longer exposure time to accom-

Table 1. Effect of peeling treatment on percentage of yield, heat penetration, color, and total solids of 'Asgrow Wonder' beets.

Peeling treatment	Mean peel & trim yield[z] (%)	Heat penetration (mm)	Color[x] L	a	b	Total solids
Lye	85.9e[y]	4.1a	12.8b	10.4b	1.4b	11.4c
Saturated steam	92.2d	3.3b	15.9a	20.7a	4.0a	11.8b
Saturated steam + H_2O	94.7c	3.1c	16.3a	20.9a	4.0a	11.9a,b
Superheated steam	95.9b	2.9c,d	16.3a	20.7a	4.0a	12.1a,b
Superheated steam + H_2O	97.7a	2.8d	16.5a	20.7a	4.0a	11.9a,b
Hand-peeled	---	---	---	---	---	12.4a

[z]Tops trimmed before peeling.
[y]Mean separation within columns by Duncan's multiple range test, 5% level.
[x]Hunter color values standardized to a red plaque where L = 68.7, a = 23.0, and b = 9.4.

plish an optimal peeling operation. Without cold water injection, the steam pressure is released more slowly and there is no direct cooling action by cold water. These roots leave the peeler hot and are not fully cooled until they pass through the washer.

Beets. Peel and trim yields in excess of 97% were attained in beets peeled with superheated steam followed by cold water injection into the peeling chamber (Table 1). Peel and trim yields were significantly less for beets peeled by superheated steam alone (95.9%), saturated steam with cold water injection (94.7%), saturated steam alone (92.2%) and by hot caustic (85.9%). All of these peeling treatments yielded a smooth, well-blanched surface, but the caustic-peeled beets were less red in color than those receiving steam treatment.

Table 2. Effect of peeling treatment on percentage of yield, heat penetration, and total solids of 'Red Jewel' sweet potatoes.

Peeling treatment	Weight (g)	Mean peel & trim yield (%)	Heat penetration (mm)	Total solids (%)
2.5 to 3.5 cm in diam				
Lye	73.8a[z]	74.2d	4.7a	20.8c
Saturated steam + H_2O	73.5a	75.0c	2.8b	21.2b,c
Superheated steam	73.8a	80.4b	2.6b	21.5b,c
Superheated steam + H_2O	75.8a	82.0a	2.4b	21.3b
Hand-peeled	---	---	---	26.4a
3.5 to 5.5 cm				
Lye	164.2a	76.3d	4.7a	22.7b
Saturated steam + H_2O	164.0a	78.9c	2.8a	22.8b
Superheated steam	164.1a	83.2b	2.6b	22.9b
Superheated steam + H_2O	164.1a	84.5a	2.4b	22.7b
Hand-peeled	---	---	---	26.2a
5.5 to 6.5 cm				
Lye	312.9a	80.1d	4.9a	24.3b
Saturated steam + H_2O	315.1a	81.7c	3.0b	24.3b
Superheated steam	315.5a	85.9b	2.5c	24.6b
Superheated steam + H_2O	330.0a	88.7a	2.4c	24.4b
Hand peeled	---	---	---	25.9a
6.5 cm				
Lye	512.4c	83.2c	4.7a	24.4c
Saturated steam + H_2O	512.0a	84.3c	2.9b	24.5b,c
Superheated steam	512.7a	89.6b	2.6c	25.0b
Superheated steam + H_2O	515.3a	91.6a	2.5c	24.9b,c
Hand-peeled	---	---	---	25.9a

[z]Mean separation within columns by Duncan's multiple range test, 5% level.

Mean heat penetration into the flesh of the beets appeared to be directly related to the duration of the heating portion of the peeling process, with greater penetration occurring in lye peeling than in steam-peeling processes (Table 1). Superheated steam peeling with cold water injection resulted in significantly lower heat penetration than saturated steam-peeling processes, while saturated steam peeling with cold water injection exhibited a significantly lower mean heat penetration than saturated steam alone.

Water uptake during the peeling and washing operations as measured by total solids (Table 1) was slightly higher in the lye-peeled beets than in those peeled by steam. Those peeled by saturated steam with cold water injection, superheated steam, and superheated steam with cold water injection were not significantly different than the mean total solids of the hand-peeled control.

Color and appearance of beets peeled by all of the steam-peeling methods were rated excellent. The color of lye-peeled roots was visibly less brilliant with a somewhat brown surface characteristic of thermal degradation of betanin. The Hunter L values confirmed that total light reflectance was lower for roots peeled by immersion in hot lye (Table 1). Hunter a values indicated that the steam-peeled beets had a more intense red surface color than the lye-peeled roots, while Hunter b values indicated that the lye-peeled beets were slightly less yellow in color than those peeled by steam processes.

Processed beets. Visual inspection of the canned, sliced beets after 1 month of storage indicated a uniform color throughout the slices in the steam-peeled samples. Pigment destruction was apparent in those areas which had come into contact with the peeling medium in the caustic-peeled slices. These areas of exposure were dull red to brown in color surface. Hunter a and b values of whole slices indicated that the flesh of the processed, lye-peeled beets was less red and less yellow in color than that of the steam-peeled beets (Table 3). This pigment destruction could result from a number of factors including: longer exposure to high temperature, exposure to high pH, and greater leaching during the peeling and washing operations.

The external color of the lye-peeled, whole, pickled beets also had a significantly lower Hunter a value and a less intense red color than the steam-peeled beets. This color difference was difficult to ascertain by visual inspection. No differences be-

Table 3. Effect of peeling treatment on the color of canned, sliced beets and processed, pickled beets

Peeling treatment	Color[z] L	a	b
Canned sliced beets			
Lye	22.0a[y]	25.4b	5.2b
Saturated steam + H_2O	20.5a	29.3a	6.3a
Superheated steam + H_2O	21.0a	30.4a	6.4a
Pickled beets—external color			
Lye	12.5a	16.1b	3.2a
Saturated steam + H_2O	13.0a	20.1a	3.4a
Superheated steam + H_2O	12.9a	19.5a	3.4a
Pickled beets—internal color			
Lye	15.0a	22.9a	3.4a
Saturated steam + H_2O	14.3a	24.7a	3.6a
Superheated steam + H_2O	14.6a	23.7a	3.5a

[z]Hunter color values standardized to a red standard where L = 68.7, a = 23.0, and b = 9.4.
[y]Mean separation within columns by Duncan's multiple range test, 5% level.

tween the internal colors of the lye-peeled and steam-peeled, pickled beets were found.

Sweet potatoes. Superheated steam with cold water injection into the steam atmosphere of the peeling chamber resulted in a higher peel and trim yield than from any of the other peeling treatments for each diameter of root examined (Table 2). Increases in peel and trim yields were observed progressing from lye peeling to saturated steam peeling with cold water injection (Table 2). These differences in peel and trim yield were constant for all sizes of sweet potatoes with the exception of those greater than 6.5 cm in diameter, where there was no significant yield difference between lye-peeled roots and roots peeled by saturated steam with cold water injection. Yields increased with increasing root size for each peeling method. This would be expected due to the decrease in surface to volume ratio in larger roots.

Mean heat penetration into the flesh of the sweet potato was greater with lye peeling than with any of the steam-peeling methods (Table 2). In the larger root sizes, superheated steam peeling resulted in lower heat penetration into the flesh than the other peeling methods.

Water uptake during the peeling and trimming opeations, as measured by total solids, varied little among peeling methods (Table 2). In roots 2.5 to 3.5 cm in diameter, water uptake was greater in the lye-peeled roots than those peeled by superheated steam with cold water injection. In roots greater than 6.5 cm in diameter, superheated steam peeling resulted in less water uptake than lye peeling.

Conclusions

The use of superheated steam resulted in better product recovery than did peeling with saturated steam or caustic solutions. Direct injection of cold water into the steam atmosphere of the peeler rapidly reduced the pressure within the peeler and thus facilitated peel removal and stopped heat penetration into the product. Better color retention was obtained from steam-peeled beets than from caustic-peeled beets.

The use of superheated steam could provide several advantages over saturated steam when used in peeling operations. With superheated steam, heat penetration into underlying tissues should be more controllable, because the thermal conductivity of superheated steam, i.e., its power to receive or give up heat to surrounding bodies, is much lower than that of saturated steam at the same pressure. Thus, assuming no loss in pressure, the amount of heat given up to the produce in the peeler represents an equivalent condensation with saturated steam, but with superheated steam, once the surface temperature of the produce to be peeled exceeds that of saturated steam at existing pressure, the heat given up to the produce represents only a decrease in the amount of superheat. This should allow the application of very hot, dry heat with less penetration beyond the outermost tissues than with saturated steam.

A second advantage of superheated steam is that it would, because of its greater temperature, allow efficient peeling at lower steam pressures. This would represent a lower requirement in total Kg of steam to be supplied to the peeler with each charging.

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