Quality of waterjet- and blade-cut romaine salad

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Abstract

Cutting operations for fresh-cut produce are usually accomplished by stainless steel knives. Waterjet cutting employs a very small stream of high-pressure water, and the type of nozzle, conveyor speed, and water pressure are the main factors that affect the quality of the cut. Two tests were conducted, cutting romaine lettuce either by an Urschel Translicer 2500 on a pilot process line using new or used and reconditioned (e.g., 3× used and sharpened) blades or by a KMT pilot waterjet system using standard or food-grade nozzles. Cut romaine showed whitening dehydration and red discoloration defects on cut surfaces. In both tests, cut romaine packaged commercially in a modified atmosphere had only minor differences in cut surface defects between blade and waterjet cutting. However, large differences due to cutting treatments were observed in cut romaine stored in bags without modified atmosphere at 2.5°C. In test 1, pieces were of very high quality with no differences between cutting method until 18 days at 2.5°C, when waterjet-cut pieces had higher visual quality with less discoloration than blade-cut pieces. New knife blades produced less damage to cut surfaces than used and reconditioned blades. The food-grade nozzle was superior to the standard waterjet nozzle. In test 2, discoloration appeared by day 9 in bags with no modified atmosphere at 2.5°C, and there were clear quality differences between cutting methods, with waterjet cutting using the food-grade nozzle better than blade cutting. There were no persistent differences in total bacterial counts between cutting methods. Potentially, improved cutting technology could reduce the need for extreme package atmospheres and/or ensure higher product quality with package leakers.

Keywords: salad-cut lettuce, cut-edge discoloration, cut-edge whitening, microbiology

INTRODUCTION

Fresh-cut products are prepared and handled to maintain their fresh state while providing convenience to the user. Preparation of these products involves cleaning, cutting, washing, trimming, coring, slicing, shredding, and other related steps, many of which increase the perishability of produce items (Cantwell and Suslow, 2002).

The preparation of fresh-cut products induces stresses that trigger a series of immediate and subsequent effects on various processes in plant tissues. The physical damage can affect cut tissues physiologically and biochemically, besides facilitating infection by pathogens. Increases in respiratory rate and ethylene production may also occur, with associated increases in rates of other biochemical reactions responsible for changes in color (including browning), flavor, texture and nutritional quality. These changes happen in the cut areas but also in tissues at a distance from the cut areas (Brecht et al., 2004; Saltveit, 2003).

One of the most damaging changes promoted by mechanical injury is the induction of phenylpropanoid metabolism, with increased activity of phenylalanine ammonia-lyase (PAL), which results in the accumulation of phenolic compounds and subsequent tissue pinking or browning by action of the enzymes polyphenol oxidase and peroxidase (López-Gálvez et al., 1996; Saltveit, 2000).

The degree of processing and quality of the equipment (e.g., blade sharpness) significantly affect the wounding response (Cantwell and Suslow, 2002; Portela and

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Cantwell, 2001), since the physiological responses of tissues to injury generally increase with the severity of the damage. Some studies have shown that respiratory metabolism and PAL activity are affected by cutting parameters such as intensity and direction (Abe et al., 1998; Deza-Durand and Petersen, 2011). According to Portela and Cantwell (2001), a blunt blade increased ethylene production, electrolyte leakage, and off-odors in fresh-cut Cantaloupe melon, but did not affect respiration, firmness, or decay compared with cutting with sharp blades.

Cutting fresh-cut produce is usually accomplished by using stainless steel knives. Using sharp blades has long been considered good practice for fresh-cut operations, but, even with sharp knives, both compression and cutting damage occurs in the tissues (Bolin et al., 1977). And, while sharp blades are recognized as very important, the protocols for sharpening and changing blades on cutting equipment vary from one fresh-cut processor to another.

Waterjet cutting has the potential to cause less damage to fresh-cut surfaces and consequently less wound-induced discoloration. Waterjet cutting technology has been used for various applications in the food industry and has been adopted by the fresh-cut industry for cutting vegetables such as celery. The basic principle is that water is pressurized by a peristaltic pump (70-400 MPa) and passed through a small nozzle to form a needle-shaped jet. The water jet cuts the produce by erosion of tissue cells, which are then removed in the small stream of water. The type of nozzle, conveyor speed, and water pressure are the main factors that determine the quality of the cut with waterjet cutting. This technique has several potential advantages besides less cutting damage, such as minimized product cross-contamination, automation, cutting versatility, and reduced blade sharpening (Becker and Gray, 1992; McGlynn et al., 2003; Carreño-Olejua et al., 2010; Jünemann et al., 2011). Studies have shown advantages of waterjet cutting such as reduced superficial browning in watermelons (McGlynn et al., 2003) and apples Carreño-Olejua et al. (2010). However, other studies have found characteristic furrows and striations caused by the high-pressure waterjet on the surface of minimally processed potatoes (Becker and Gray, 1992) and carrots (Tatsumi et al., 1993) when compared with conventional cutting with sharp blades.

The objectives of this study were:

1) To compare blade cutting and waterjet cutting on the same lot of lettuce under pilot scale conditions, and
2) To determine whether there were differences in quality, shelf-life and microbial load of salad-cut romaine in relation to cutting method.

MATERIALS AND METHODS

Tests were conducted using Salinas field-grown romaine lettuces ('Green Forest' for test 1, harvested June 2013; 'Sun Valley' for test 2, harvested August 2013), in which the same lots of lettuce were prepared by different cutting methods. Product was harvested, cooled and staged at the two locations where the cutting lines were set up (Salinas and Davis) so that processing could be done at the same time. The lettuce was cut into salad-size pieces (about 2”×2") in both process lines.

Lettuce was cut by an Urschel Translicer 2500 on a pilot process line using new or used and reconditioned (e.g., 3× used and sharpened) stainless steel blades. After cutting, lettuce was immediately dumped into a flume with chlorinated water (7.5 ppm free chlorine at pH 6.5-7.5), centrifuged and packaged in nitrogen-flushed retail modified atmosphere packaging (MAP) bags; a separate lot of unsealed packages was also prepared and transported under cold conditions to Davis for evaluation.

Lettuce from the same field lot was cut on a KMT pilot waterjet system at Davis using a standard nozzle (sapphire orifice) or a food-grade nozzle (diamond orifice) manufactured by KMT. In test 1, the standard nozzle was used at 35,000 psi with a conveyor speed of 50 feet per min and the food-grade nozzle was used at 55,000 psi with a conveyor speed of 25 feet per min. Based on previous work, these represented expected worst- and best-case scenarios for waterjet cutting (M.I. Cantwell, unpublished data). In test 2, only the food-grade nozzle was used, at the same conveyor speed but at either 35,000 or 55,000 psi.

Groups of four romaine heads were halved longitudinally by waterjet, placed cut-face-down and passed again through the waterjet system to obtain the salad-size pieces. After waterjet cutting, pieces were immediately dropped into cold chlorinated water (10:1 water volume: lettuce mass ratio) for 25 sec with agitation (same batch of chlorinated water as used on the blade pilot line) and manually centrifuged (Dynamic salad spinner model 06140, 30 revolutions) and 100-150 g product were packed in unsealed polyethylene bags and stored at 2.5°C. A separate quantity of product was transported in coolers with ice to Salinas, where it was packaged in retail salad bags and evaluated there. The time between cutting and packaging at both locations did not exceed 4 h.

Product was assessed periodically for overall marketable quality and defects. Cut-surface defects included red discoloration and whitening dehydration, and were evaluated at Davis on rating scales of 1 to 5, where 1 = none, 2 = slight, 3 = moderate, 4 = moderately severe, and 5 = severe. Overall marketable quality was scored on a scale from 9 to 1, where 9 = excellent, 7 = good, 5 = fair, 3 = poor, and 1 = unusable, with a score of 6 considered the limit of marketability. Decay was negligible in both tests. In Salinas, cut romaine packaged in MAP was evaluated for the same defects but as the number of pieces showing the defect, with 18 bags per evaluation. Most of the data presented here are from the Davis evaluations of salad product held at 2.5°C without modified atmosphere.

Respiration rates were measured on 100 g product in containers at 2.5°C connected to a flow of humidified air controlled by capillaries to allow accumulation of CO_2 to about 0.5%. The inlet and exit CO_2 concentrations were measured daily by taking 1 mL gas samples and injecting into an infrared analyzer calibrated with a 0.5% CO_2 standard. Respiration rates were calculated as µL CO_2 g^{-1} h^{-1}.

Total bacterial counts are reported for product stored at Davis. Twenty-five grams of cut lettuce without midrib was added to 225 ml BPW buffer for 30 sec in a Pulsifier (no maceration). Dilutions were plated on plate count agar and incubated at 29°C for 48 h. Respiration rates were determined on salad-cut romaine stored in air by measurement of CO_2 production on an infrared analyzer and expressed as µL CO_2 g^{-1} h^{-1}.

Quality evaluations are based on four replicates of 50 (test 1) or 35 (test 2) pieces each per treatment per evaluation. Quality data were analyzed by ANOVA with mean separation by LSD.05 (Sigmastat 11.0). Respiration data are means from four replicates of 150 g each ± standard deviation, and microbial data are means from three replicates ± standard deviation.

RESULTS AND DISCUSSION

Cut romaine in MAP had only minor differences in cut-surface defects between blade and waterjet cutting. Atmospheres in the MAP retail bags at 4.4°C were <4% O_2 + 4% CO_2 and <0.1% O_2 + 9% CO_2 after 1 and 12 days, respectively, and atmospheres were not different for lettuce from different cutting methods. In test 1 in non-MAP packaging, there were no significant differences in product defects due to cutting methods up to day 12. Clear differences were observed on day 18. In test 2, the salad-cut romaine in non-MAP bags began to show defects by day 9, and there were significant differences due to cutting method by day 12. More discoloration and whitening were found in product cut by used and sharpened knives, while product from the other three cutting methods was rated the same. The former product was deemed unmarketable (acceptability score was poor) by day 12.

Storing product in air at 2.5°C allowed differentiation among treatments because there was no modified atmosphere to cover up the consequences of cutting damage. Decay was negligible in both tests. The lettuce was of very high quality in test 1, and no differences were observed among cutting methods until after 12 days at 2.5°C (Figure 1A-C). A final evaluation on day 18, however, showed that lettuce cut by waterjet with a food-grade nozzle had better visual quality and reduced discoloration compared with other cutting methods. Also, product cut with new knives was slightly better than that cut with used and sharpened knives. Differences in surface whitening followed the same trends as discoloration (Figure 1C).

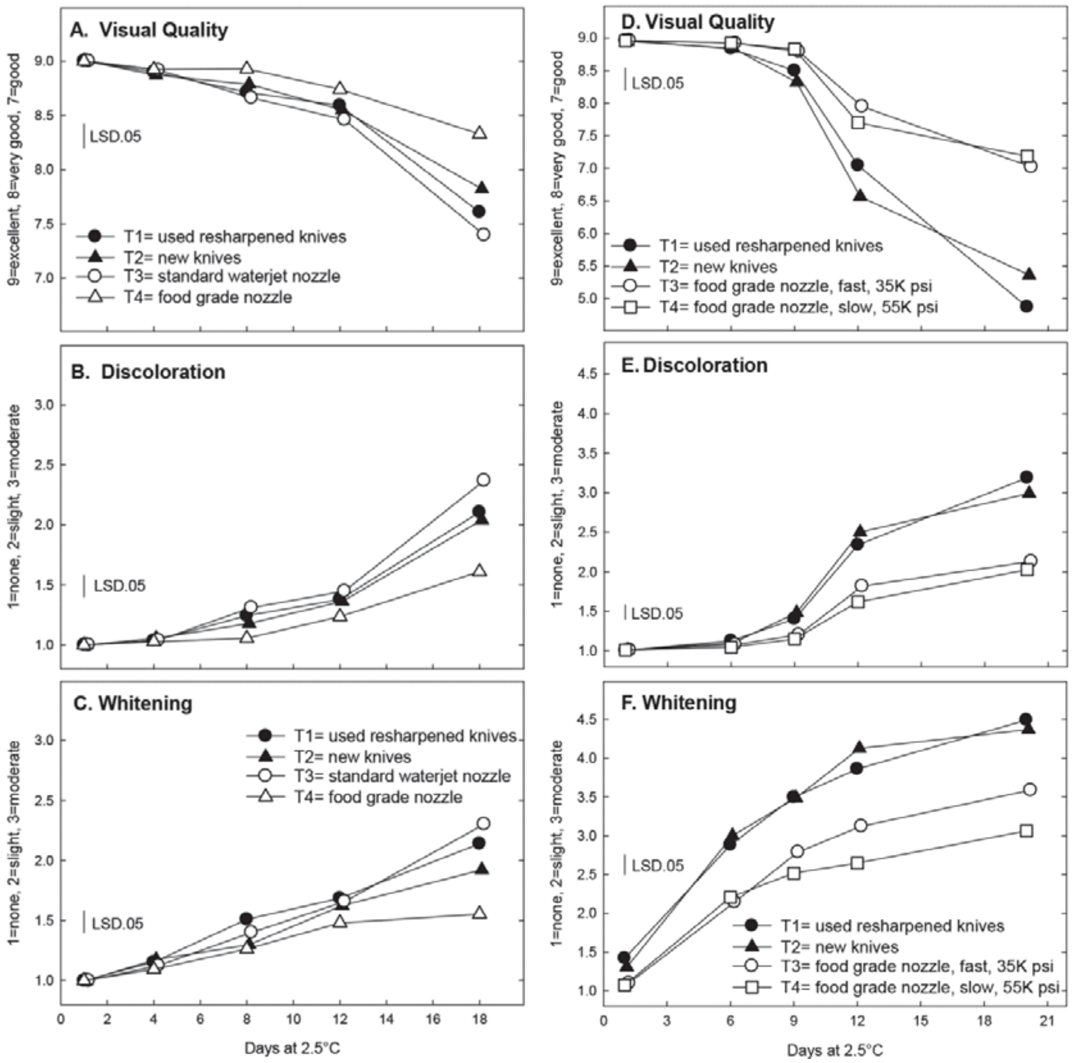

Figure 1. Overall visual quality (A, D), cut-edge discoloration (B, E) and cut-edge whitening (C, F) of salad-cut romaine 'Green Forest' (A-C) and 'Sun Valley' (D-F) prepared by four methods of cutting (A-C) and by stainless steel blades or by food-grade waterjet nozzles (D-F) and stored in air at 2.5°C. A visual quality score of 6 indicates the limit of marketability. Test 1 data (A-C) are means of four replicates of 50 pieces each, and test 2 data (D-F) are means of four replicates of 35 pieces, with mean separation by LSD.05.

In test 2, differences were observed by 9 days at 2.5°C (Figure 1D-F). After 12 days, there was a clear distinction between the romaine cut by waterjet and knives, with significantly less discoloration and whitening in the waterjet-cut product. Knife-blade-cut romaine reached the limit of salability at about 14 days, while waterjet-cut product was still of marketable quality at 21 days. The waterjet parameters of pressure and conveyor speed did not affect the romaine quality. Differences in knife blades did not affect quality changes in test 2 either.

In test 1, no important differences were observed in total bacterial counts after 8 or 12 days, although there were significant differences on day 1 (Table 1). In test 2, total bacterial counts did not differ among treatments on any days of evaluation (1, 8 or 12; data not shown).

Table 1. Total bacterial count (log CFU g^{-1}) of salad-cut romaine lettuce 'Green Forest' stored in air at 2.5°C. Lettuce was cut by four different methods. Data are means of triplicates ± standard deviation.

Cutting method	Day 1	Day 8	Day 12
Used, resharpened knives	3.76±0.18	6.74±0.02	5.13±0.10
New knives	3.99±0.25	6.55±0.32	5.25±0.13
Standard waterjet nozzle	3.11±0.52	6.50±0.07	4.93±0.29
Food-grade waterjet nozzle	2.41±0.36	6.46±0.05	4.36±0.27

Respiration rates of salad-cut romaine in test 2 were similar among cutting methods (Figure 2). Measurements were made over the first 6 days of storage, but it appears that there was no impact of cutting method. Respiration rates averaged 7µL g^{-1} h^{-1} over the 6-day period and were consistent with previous measurements on cut romaine (M.I. Cantwell, unpublished data).

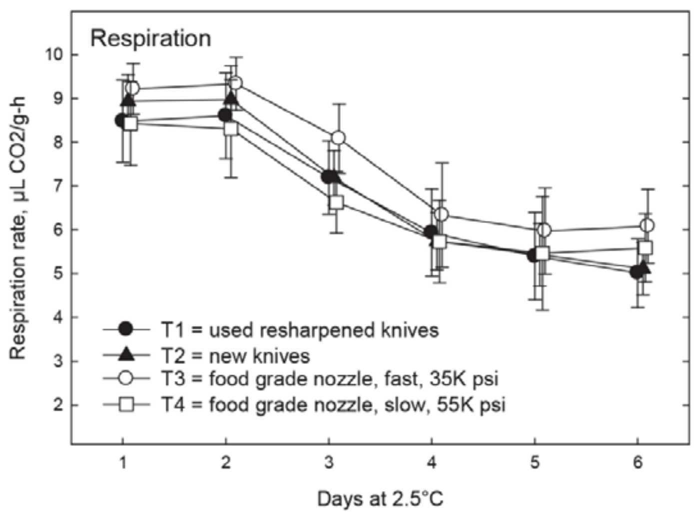

Figure 2. Respiration rates of salad-cut romaine 'Sun Valley' prepared by stainless steel blades or by food-grade waterjet nozzles and stored in air at 2.5°C. Data are means of four replicates ± standard deviation.

CONCLUSIONS

Minimizing cutting damage reduced discoloration in salad-cut romaine. MAP provided good control of cut-lettuce surface defects regardless of cutting method. Without MAP (simulating package leakers), however, better salad-cut romaine quality was obtained with waterjet cutting using a food-grade nozzle. A standard waterjet nozzle caused damage similar to that caused by knife blades. Although initial bacterial counts may be lower with waterjet cutting, no differences in microbial load during storage were found due to cutting method.

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