

Temperatures experienced by fresh-cut leafy greens during retail storage and display

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Abstract

There has been limited published work in the United States on temperature profiling of fresh-cut, bagged leafy greens during their transport, retail storage, and retail display. This study utilized temperature monitors placed in backrooms and display cases at nine supermarkets located in southern California: the Central Coast (Santa Barbara to Los Osos), Greater Los Angeles (Burbank area), and Greater Palm Desert. Sensors were installed midway along each 8-foot display case section containing fresh-cut leafy greens. Monitors were placed at the front and back of shelves and in the lower bin. In storage rooms, sensors were placed 4 feet from the floor in each corner. High and low temperature abuse occurred in retail display cases, with slightly more than 40% of the sensors indicating temperatures $>7.22^{\circ}\text{C}$, and 17% of the sensors indicating temperatures $<-0.17^{\circ}\text{C}$, for at least 5% of the time. Temperatures in storage rooms were rarely too low, but were often too high: slightly more than 58% of the sensors indicated temperatures $>7.22^{\circ}\text{C}$ more than 5% of the time, and five sensors measured continuous temperatures $>7.22^{\circ}\text{C}$ for nearly a year. Overall, most temperature abuse of pre-cut leafy greens at the retail level occurred during backroom storage. This study should be expanded to include major grocery chains in cities across the United States in order to verify these results.

Keywords: Romaine, lettuce, supermarket, *Listeria monocytogenes*, *Escherichia coli* O157:H7, food safety, backroom

INTRODUCTION

Food-borne pathogens are a continued public-health and grower-packer concern because of their persistence in processing and distribution environments. Numerous studies have identified *Listeria monocytogenes* and *Escherichia coli* O157:H7 as pathogens of great concern during the postharvest handling of whole and fresh-cut produce (Johnston et al., 2005; FDA, 2006a, 2010, 2014; DeNoon, 2011; Brown et al., 2016). More than 800 illnesses and eight deaths have been associated with the consumption of fresh-cut produce, specifically leafy greens, spinach and lettuce, grown in California (FDA, 2005). Widely distributed in nature, *Listeria* has received much attention and concern because of its ability to grow at refrigeration temperatures (Junttila et al., 1988; Walker et al., 1990; Todar, 2012; Zeng et al., 2014).

Over the past decade, *L. monocytogenes* and *E. coli* O157:H7 have been implicated in numerous recalls. In 2006, California-grown, baby flat-leaf spinach caused more than 200 cases of *E. coli* O157:H7 infection in 28 states, resulting in three deaths and 31 confirmed cases of hemolytic uremic syndrome (FDA, 2006b). In 2011, cantaloupe contaminated with *L. monocytogenes* caused 147 cases of listeriosis, resulting in 33 deaths and one miscarriage (CDC, 2012). Since 2010, there have been eight recalls due to possible contamination by *L. monocytogenes* (Zeng et al., 2014).

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Growth of *E. coli* O157:H7 at refrigeration temperatures has been reported on fresh-cut leafy greens at 10°C and above (Koseki and Isobe, 2005), with decreased populations at 12°C after 14 days of storage with shredded lettuce (Abdul-Raouf et al., 1993).

Previous work by Beuchat and Brackett (1990) suggested that, at temperatures below 10°C, there may not be a substantial risk of growth for *L. monocytogenes* on shredded lettuce. However, more recent studies by O'Beirne et al. (2015) and Zeng et al. (2014) have suggested growth of *L. monocytogenes* on shredded lettuce under reduced oxygen atmospheres, with estimated minimum growth thresholds depending on the strain of the pathogen.

Published studies suggest the potential for growth during retail storage and display (Zeng et al., 2014; Brown et al., 2016). Limited published work has been done on retail temperature profiling of fresh-cut leafy greens and bagged salads in the United States (Nunes et al., 2009; Kou et al., 2015). This objective of this study was to monitor and profile the temperature of bagged salads during handling and distribution at retail stores in Southern California. The upper threshold for temperature abuse of 7.2°C was chosen based on standard industry practice. A lower limit of -0.17°C was considered an abusive temperature as it is just above the freezing point of lettuce as reported by Cantwell and Suslow (2013) and Hardenburg et al. (1986).

MATERIALS AND METHODS

From 2011 to 2012, temperature monitors were placed in both cold-storage rooms and display cases at nine locations in three geographic regions of Southern California: the Central Coast (Santa Barbara to Los Osos), Greater Los Angeles (Burbank area), and the Greater Palm Desert. Display cases were monitored for ~2 months during both summer and winter. The cold storage rooms, located at the back of each store, were monitored continuously for approximately 1 year.

Eight, 60-day Ultra Contact Labels (PakSense, Boise, ID, USA) were installed midway along each 8-foot display case containing fresh-cut, leafy greens. Monitors were placed at the front of shelves 1, 2, 3, 5 and 6, and at the back of each case under shelves 1, 3 and 5 (Figure 1a). If a store had multiple display cases containing fresh-cut produce, sensors were installed in each display case using the same protocol. The 60-day Ultra Contact Labels had a 1 minute sampling frequency and were accurate to within $\pm 0.5^\circ\text{C}$ between -10 and 30°C (<http://www.paksense.com/products/ultra-contact>).

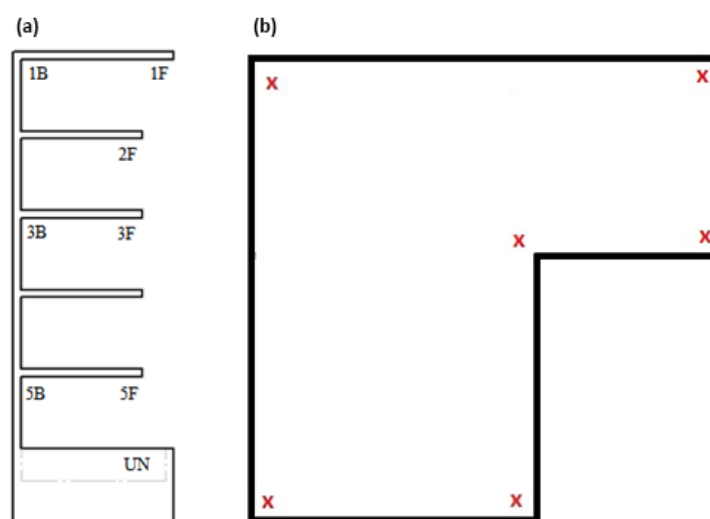


Figure 1. (a) Location of temperature monitors in display cases at retail locations. B, Back; F, front; UN, underneath (salads bags in lower bin). (b) Location of temperature monitors in cold-storage rooms at retail locations: atypical room configuration.

In the storage rooms, TempTale®4 monitors (Sensitech, Beverly, MA, USA) were placed 4 feet from the floor in each corner. The storage rooms were typically shaped as large rectangles, and only required four sensors; however, in two locations, the storage room was shaped as an “L” and required an additional two sensors (Figure 1b). The TempTale®4 monitors were programmable and, in this study, the monitors were set to a 15-minute sampling frequency.

Data analysis

Retail data were analyzed using MATLAB (v. 7.0) software (Mathworks, Natick, MA, USA). Each sensor temperature-profile was analyzed for percentage of time, longest uninterrupted interval, and average interval above or below -0.17 or 7.22°C . The profiles were then compiled to determine overall data trends.

RESULTS

Display cases

High-temperature abuse was recorded in all nine of the monitored display cases (Table 1). Ninety-six of the 239 temperature sensors used in this study recorded temperatures above 7.22°C for at least 5% of the total time (~2 months) that they were installed in the display cases. One sensor recorded temperatures above 7.22°C for more than 65% of the total time. The highest temperature recorded during the study was 27.6°C . The longest uninterrupted interval above 7.22°C was 240 h, or 10 days.

Table 1. Type of abuse recorded at each retail location in southern California.

Location	Region	Retail display case		Back storage room	
		$<-0.17^{\circ}\text{C}$	$>7.22^{\circ}\text{C}$	$<-0.17^{\circ}\text{C}$	$>7.22^{\circ}\text{C}$
Palm Springs	Southwest Desert	-	x ¹	-	x
Burbank	South Coast	x	x	-	-
Palm Desert	Southwest Desert	-	x	-	x
Los Osos	Central Coast	x	x	-	-
Palm Springs	Southwest Desert	x	x	-	x
Santa Barbara	Central Coast	-	x	-	x
Burbank	South Coast	x	x	-	x
San Luis Obispo	Central Coast	x	x	-	x
Burbank	South Coast	-	x	-	-

¹“x” indicates that temperatures exceeding the threshold was observed at the location.

Low-temperature abuse was recorded for at least 5% of the time in five of the nine display cases (Table 1). Forty-one of the 239 temperature sensors recorded temperatures below -0.17°C for at least 5% of the time (~2 months) that they were monitored. One sensor recorded temperatures below -0.17°C for more than 86% of the total time. The lowest temperature recorded was -2.83°C . The longest interval below -0.17°C was 14.5 h.

Though not analyzed statistically, a review of the data indicated that temperatures were often too high at the top and too low at the bottom (in the well) of the display cases (data not shown).

Retail storage rooms

High-temperature abuse was recorded for at least 5% of the time in six of the nine monitored storage rooms (Table 1). Sixty-five of the 112 temperature sensors recorded temperatures above 7.22°C for more than 5% of the time. Five of the 112 temperature sensors never recorded temperatures below 7.22°C for the duration of the study, which was approximately 1 year. The highest temperature recorded was 19.56°C .

In all nine storage rooms, low-temperature abuse was absent or minimal. No sensor

recorded temperatures below -0.17°C more than 1% of the total time that temperatures were monitored.

DISCUSSION

High-temperature abuse occurred in retail display cases, with slightly more than 40% of the sensors indicating temperatures above 7.22°C for more than 5% of the time. Low-temperature abuse occurred as well, with slightly more than 17% of the sensors indicating temperatures below -0.17°C for at least 5% of the time. The longest uninterrupted interval above 7.22°C was 240 h, and the lowest uninterrupted interval below -0.17°C was 14.5 h. However, subsequent work based, in part, on temperature profiles generated in this study has shown little growth of *E. coli* O157:H7 on pre-cut leafy greens during 72 h simulated retail display, though *L. monocytogenes* populations increased ~ 1 log cfu g^{-1} during this same period (Zeng et al., 2014).

No significant low-temperature abuse occurred in any of the storage rooms. Data indicated that temperatures in storage rooms were set too high, as slightly more than 58% of the sensors indicated temperatures $>7.22^{\circ}\text{C}$ more than 5% of the time. In fact, five of the sensors never indicated a temperature below 7.22°C , over a period of nearly a year. Subsequent work based, in part, on temperature profiles generated in this study has shown growth of *E. coli* O157:H7 and *L. monocytogenes* of ~ 3 log cfu g^{-1} on pre-cut leafy greens during 72 h of simulated retail storage (Zeng et al., 2014).

Microbial work based on five representative high-temperature abuse profiles generated from a related transport study (Brown et al., 2016) has shown no growth of *E. coli* O157:H7 during 48-52 h of simulated transport, while *L. monocytogenes* populations increased ≤ 0.6 log cfu g^{-1} under the same conditions (Zeng et al., 2014).

CONCLUSIONS

Microbial work based on abuse profiles generated in a related study found no growth of *E. coli* O157:H7 during simulated transport, while *L. monocytogenes* populations increased by less than ≤ 0.6 log cfu g^{-1} . Likewise, there was little growth of *E. coli* O157:H7 on pre-cut leafy greens during 72 h simulated retail display, though *L. monocytogenes* populations increased by ~ 1 log cfu g^{-1} during this same period. In contrast, high-temperature abuse was more of a concern in retail storage rooms, and subsequent work has shown growth of *E. coli* O157:H7 and *L. monocytogenes* of ~ 3 log cfu g^{-1} on pre-cut leafy greens during 72 h of simulated retail storage. These results clearly indicate that more stores in cities across the U.S. should be monitored to better assess the potential for and degree of temperature abuse to which pre-cut-leafy greens are subjected. In addition, transport temperatures from distribution centers to retail receiving docks should be monitored. This will result in a complete temperature profile for pre-cut leafy greens – from processing centers through retail display – which will enable food safety risks for these products to be more accurately assessed.

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