



## Short hot water as safe treatment induces chilling tolerance and antioxidant enzymes, prevents decay and maintains quality of cold-stored cucumbers

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### ABSTRACT

This study investigated the effects of treating cucumbers with short hot water dipping at 45 (SHW45) and 55 °C (SHW55) for 5 min compared to fruit dipped in 25 °C water (C). The purpose was to alleviate chilling injury, prevent decay, maintain sensory quality and induce antioxidant enzymes during storage. The cucumbers were held at 4 °C for 7, 14 and 21 d and shelf life at 20 °C for 2 and 4 d. Weight loss, appearance, decay, color, firmness, taste, soluble solids content (SSC), chilling injury (CI), total, reducing and non-reducing sugars, phenolics, electrolyte leakage (EL), peroxidase (POD) and catalase (CAT) activity were measured. The results revealed that SHW55 treatment had the lowest weight loss, CI, EL and POD activity, and had the best appearance, color, taste, and the highest CAT activity during cold storage and shelf life compared with C and SHW45. However, no significant effects were found between C, SHW45 and SHW55 on total, reducing sugars and SSC. No decay appeared on cucumber fruit with SHW55 treatment during the storage period. It may be possible to use SHW55 in a packinghouse as a safe commercial treatment to maintain quality, prevent decay and mitigate chilling injury, prolong storage period and possibility to store cucumber fruit at a non-optimal low temperature.

### 1. Introduction

The cucumber (*Cucumis sativus* L.) plant is belonging to the family Cucurbitaceae. Cucumbers are grown to be eaten fresh and to use in pickles. Using cucumbers as a fresh vegetable has been increasing, while pickles consumption has been reducing (Minor and Bond, 2017). The area of cucumbers in Egypt was 20875 Ha, and the total production was 473774 t in 2014 [FAOSTAT, 2017, date available at <http://www.fao.org/faostat/en/#data/QC>]. Cucumbers are among several tropical and subtropical plants which are sensitive to cool temperatures. Cucumbers are often transported and stored under cold temperature 10–13 °C, the optimum temperature to store cucumbers is 12 °C, while the storage below 7 °C causes chilling injury (Kader, 2011), and results in physiological and morphological changes (Fukushima et al., 1977; Tsuchida et al., 2010).

Heat treatment is an effective nonchemical method and environment-friendly technology to control postharvest physiological disorders (Lu et al., 2007). Heat treatments may control decay, reduce chilling injury and maintain vegetables and fruit quality (Escribano and Mitcham, 2014). Huan et al. (2017) found that hot water treatment was effective in alleviating chilling injury and maintaining peach quality. Heat treatment induced the resistance for diseases in peach (Liu et al., 2012), reduced decay and activated antioxidant enzymes such as

catalase in tomato (Boonkorn, 2016). Immersion of cucumbers in hot water at 42 °C for 30 min before the storage at 12 or 2.5 °C induced physiological changes (McCollum et al., 1995). Vapor heat treatment of cucumbers at 48 °C for 8 min decreased softening and electrolyte leakage (Kasim and Kasim, 2011). Hot water treatment (40 °C for 30 or 50 min) intermittently had the lowest decay and weight loss and highest catalase activity, and delayed cucumbers ripening during storage at 10 °C (Zhang et al., 2014).

Current postharvest diseases management depend on the synthetic compounds, but fungicide resistance, tighter regulations and their impact on the human health and environment led to the researches for new strategies for management of diseases (Escribano and Mitcham, 2014), and maintained quality of fruit. Many fruit and vegetables tolerate the water temperatures of 50–60 °C for 10 min, the exposure to these temperatures for short period can control several postharvest pathogens, but hot water dipping at 46 °C requires 90 min (Lurie, 1998). Furthermore, the short hot water treatment is a safe treatment, a technology cheaper, easier, more feasible and can be incorporated into sorting line in the packinghouse. Now few studies have investigated the effects of short hot water dipping on sensory quality, chilling injury and antioxidant enzymes of cold-stored cucumbers at a non-optimal low temperature. Also, there is very little information about cucumbers quality and decay during shelf life (retail sale period) after low

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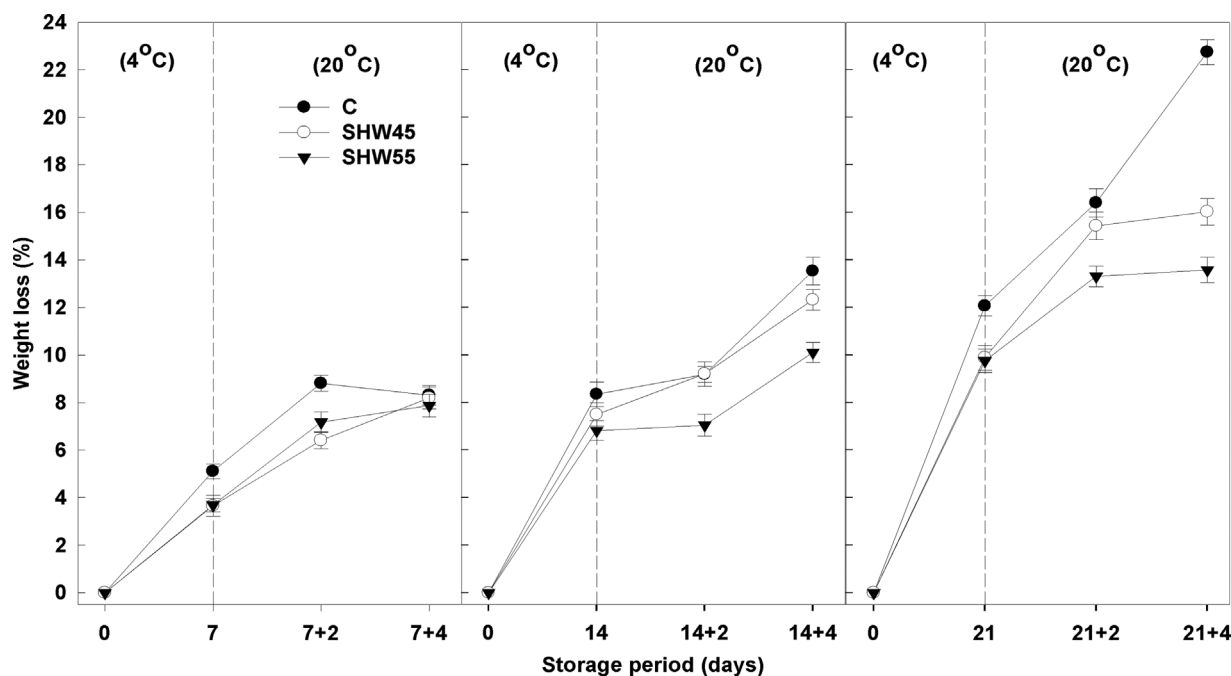


Fig. 1. Effect of short hot water dipping treatment on weight loss of cucumbers after storage at 4 °C and shelf life at 20 °C. Values are the mean of n = 3 and vertical lines represent the standard error.

Table 1

Appearance, decay, taste, chilling injury, firmness, SSC of cucumbers after storage at 4 °C and shelf life at 20 °C.

Characters	Treatments	at harvest	Cold storage + shelf life periods (days)											
			7	7 + 2	7 + 4	14	14 + 2	14 + 4	21	21 + 2	21 + 4	Main <sup>+</sup>		
Index number	Appearance*	C	9	9.00a	7.00bc	7.00bc	6.33cd	5.67de	3.00g	1.67h	1.00h	1.00h	4.63C	
		SHW45	9	9.00a	7.00bc	7.00bc	7.00bc	6.33cd	5.00ef	4.33f	1.00h	1.00h	5.29B	
		SHW55	9	9.00a	7.67b	7.00bc	7.00bc	6.33cd	5.00ef	7.00bc	5.67de	5.00ef	6.63A	
		Main <sup>++</sup>	9.00A	7.22B	7.00B	6.78B	6.11C	4.33D	4.33D	2.56E	2.33E			
Decay**	C	1	1.00g	1.00g	1.00g	1.00g	1.00g	1.00g	1.00g	1.00g	2.67d	4.00b	5.00a	2.04A
		SHW45	1	1.00g	1.00g	1.00g	1.00g	1.00g	1.00g	1.00g	2.00e	3.67c	1.41B	
		SHW55	1	1.00g	1.00g	1.00g	1.00g	1.00g	1.00g	1.00g	1.00g	1.00g	1.00C	
		Main <sup>++</sup>	1.00E	1.00E	1.00E	1.00E	1.00E	1.22D	1.56C	2.33B	3.22A			
Taste***	C	5	5.00a	5.00a	4.67ab	4.00cd	4.00cd	1.33h	1.00h	1.00h	1.00h	3.00C		
		SHW45	5	5.00a	5.00a	5.00a	4.33bc	4.00bc	3.00f	3.00f	2.00g	1.00h	3.59B	
		SHW55	5	5.00a	5.00a	5.00a	4.33bc	4.00cd	3.00f	3.67de	3.33ef	3.00f	4.04A	
		Main <sup>++</sup>	5.00A	5.00A	4.89A	4.22B	4.00B	2.44C	2.56C	2.11D	1.67E			
CI****	C	1	1.00f	1.00f	1.00f	4.00b	3.67b	4.00b	4.00b	4.00b	4.00b	5.00a	3.07A	
		SHW45	1	1.00f	1.00f	1.00f	3.00c	3.67b	3.00c	3.00c	3.00c	4.00b	2.52A	
		SHW55	1	1.00f	1.00f	1.00f	1.67e	2.33d	2.33d	1.67e	1.67e	2.33d	1.67B	
		Main <sup>++</sup>	1.00D	1.00D	1.00D	2.89C	3.00BC	3.33B	2.89C	2.89C	3.78A			
Firmness (N)	C	5	3.92fg	4.50cde	5.00ab	3.50h	4.00fg	4.67bc	3.75gh	2.83i	3.50h	3.96B		
		SHW45	5	4.83bc	4.58 cd	5.33a	4.25def	4.50cde	4.83bc	4.50ede	4.17ef	4.17ef	4.57A	
		SHW55	5	4.67bc	4.75bc	4.50cde	4.83bc	4.77bc	5.00ab	5.00ab	4.75bc	4.58cd	4.76A	
		Main <sup>++</sup>	4.47C	4.61BC	4.94A	4.19DE	4.42CD	4.83AB	4.42CD	3.92F	4.08EF			
SSC%	C	5	5.00abc	5.00abc	5.50a	5.20ab	5.50a	5.00abc	5.00abc	4.00de	3.80e	4.00de	4.78A	
		SHW45	5	5.00abc	5.00abc	5.00abc	5.00abc	5.00abc	5.00abc	5.00abc	4.50cd	4.50cd	4.94A	
		SHW55	5	5.00abc	4.50 cd	4.50 cd	5.00abc	4.80bc	5.00abc	4.50cd	4.50cd	5.20ab	4.78A	
		Main <sup>++</sup>	5.00AB	4.83AB	5.00AB	5.07A	5.10A	5.00AB	4.50CD	4.27D	4.73BC			

The values within a column with different letters are significantly different at  $p \leq 0.001\%$  according to the least significance difference test. Values are the mean of three replicates. + mean of short dipping treatment. ++ mean of cold storage and shelf life periods. \*Appearance; 9 = excellent, 7 = very good, 5 = good, 3 = fair, and 1 = poor, inedible. \*\*Decay; 5 = severe, 4 = moderately severe, 3 = moderate, 2 = slight and 1 = none. \*\*\*Taste; 5 = fully typical, 4 = moderately full, 3 = moderate, 2 = slight and 1 = none. \*\*\*\*Chilling injury; 1 = no injury, 2 = slight, 3 = moderate, 4 = moderately severe, 5 = severe.

temperature storage. Therefore, the objective of this investigation was to test the hypothesis that the short hot water dipping could be used to reduce chilling injury symptoms, prevent decay, maintain the quality, prolong the storage period in low temperature storage 4 °C and shelf life at 20 °C. At the same time, study the effects of short hot water dipping on antioxidant enzymes in cucumbers.

## 2. Materials and methods

### 2.1. Plant materials

Organic cucumbers cv ‘Dahshan’ grown under greenhouse were freshly harvested at commercial maturity (about 15 cm in length, dark green, firm, and turgid and the seeds are still succulent) from an organic

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