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Kinetic reduction of UV-C against *Salmonella* Typhimurium contaminated on radish sprouts (*Raphanus sativus* L.)

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Abstract Consumer demand for fresh, healthy and contain large amounts of nutrious products has significantly increased the minimally processed ready-to-eat (RTE) vegetable. Sprouts are primary recognized as RTE. Unfortunathely, the frequency of reports about foodborne outbreaks resulted form sprouts consumption has increased. Interventions were highly required to minimize the contamination. This study presented the kinetic reduction of *Salmonella* Typhimurium contaminated on Radish sprouts using UV-C at 3.2 to 12.8 W/m^3 under different washing systems. The reduction of *S*. Typhimurium increased when the intensity of UV-C increased. UV-C at 12.8 W/m^3 for 30 min in dynamic washing system reduced the population of *S*. Typhimurium on Radish sprouts around 2.0 $Log_{10}CFU.g^{-1}$ with different statistical significance ($p \leq 0.05$). In addition, the kinetic reduction of *S*. Typhimurium on Radish sprouts was studied. The highest intensity of UV-C at 12.8 W/m^3 demonstrated the highest rate of reduction (k-value) against *S*. Typhimurium. The highest k-value was $6.7x10^{-3}$ ln $CFU.g^{-1}.min^{-1}$ under dynamic washing system. However, the effect of low temperature indicated that the reduction rate was not depended on the change of temperature. Conclusively, the reduction effect of UV-C was increased when the intersity of UV-C and contact time increased. Moreover, the temperature had an ineffectiveness on the reduction of *S*. Typhimurium contaminated on Radish sprouts. Therefore, UV-C with different washing systems might be alternated for safety use the radish sprouts process.

Keywords: UV-C, Radish sprouts, *Salmonella* Typhimurium, Kinetics reduction, Minimally process

Introduction

Sprouts are fresh products which contain essential components of consumption. Moreover, consumers significantly change in lifestyles and the concerns about food safety are one of the factors as well. Unfortunately, fresh sprouts contain bacterial contamination including foodborne pathogens such as *Escherichiia coli* O157:H7, *Salmonella* Typhimurium, *Listeria monocytogenes* and *Stapphyloccoccus aureus* (Rajkowski and Thayer, 2000). In 1998, around 140 cases in the United Kingdom associated with the consumption of raw Mung been sprouts were reported. These

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outbreaks were caused from *Salmonella* Saint-Paul. The outbreak of *Salmonella* Newport on alfalfa sprouts was occurred in 1995 to 1996 that associated to illness case around 133 people in many large countries form United States, Denmark and Canada. In Japan, Radish sprouts were linked to associated outbreak in school at *1154pprox.* 10,000 cases were reported (Taormina *et al.*, 1999). Thus, the effective decontamination for eliminating foodborne pathogens on fresh sprouts should be developed to reach the safety level for consumption. The major factor was seed contaminations so there were many researches associated to decontamination microorganism on seed sprouts. Treatments of seeds with 20,000 ppm of Hypochlorite solution was recommended by Food and Drug Administrations (FDA) to reduce microorganism but in some case, it is not enough to prevent the contaminations (Zhang *et al.*, 2011). The recontamination was also detected because of the sprouting environment that supported the growth of such microorganism. In addition, the main factor of contamination to sprout was soil, seed and water contamination (Yang *et al.*, 2013). Thus, foodborne pathogens can be contaminated to sprouts especially for pre-harvest to distribution. So, the processes of foodborne pathogens decontamination are still important for fresh products.

Minimally processes have been popular for using in fresh sprouts production than thermal process because that process can preserve the essential nutrients. However, there are many reports showed that the minimally process cannot elimination foodborne pathogen to safety level for consumptions (Lee *et al.*, 2018). Ultraviolet radiation (UV) is one such of technology to develop in nonthermal processes and has many advantages in sanitation methods because UV fewer changes the nutrition of food including sensory quality (Chun *et al.*, 2010). Ultraviolet radiation type C (254 to 270 nm) has been approved by FDA. It can use for reduction microorganism on surface of food or food contact surfaces (FDA, 2017). UV-C can eliminate most of microorganism. UV-C radiation can be absorbed by DNA of target microorganisms and proteins in cell and resulted in conformation changes and damaged to DNA replication system (Buma *et al.*, 2003; Ha *et al.*, 2016). UV-C was used to inactivate microorganisms in fresh strawberry and lettuce (Birmpa *et al.*, 2013). The results indicated that UV-C presented the reduction effect against of *E. coli* and *Salmonella* sp. Targets microorganism were achieved to 2.5 log reduction in dosages up to 64.4 J/cm^2. In liquid egg and apple juice contaminated by *E. coli* O157:H7 approx. 8.00 Log$_{10}$ CFU/g^1 was reduced to 3.80 Log$_{10}$ CFU/g^1 at 5 mW/min.cm^2, when using UV-C treating to both food products (Ngadi *et al.*, 2003).

This study was aimed to investigate the use of UV-C on decontamination of *S.* Typhimurium ATCC 13311 contaminated on and inside of Radish sprouts under different washing systems.

Materials and methods

Preparation of fresh Radish sprouts

Radish sprouts were germinated in sterile condtion. The harvesting would be done on the 5th day after germination. The fresh sprouts were washed with sterlied water followed by 5,000 ppm sodium hypochlorite for 20 min. Chlorine residues were neutralized by 5 g L^{-1} sodium thiosulfate solution. Sterlied fresh sproutswere stored at room temperature (29±2 ℃). Prepatation of culture and inoculum.

Table 1. Treatment of *S*. Typhimurium decontamination

System	Level of contamination	System of water	Type of water	Temperature(°C)
1	High/Low	Dynamic	Sterile	25±2
2	High/Low	Dynamic	Continuous	25±2
3	High/Low	Static	Sterile	25±2
4	High/Low	Static	Continuous	25±2
5	High/Low	Dynamic	Sterile	10±2

Stock culture of *S. Typhimurium* ATCC 1331 (Department of Medical Sciences, Thailand) was activated in 50 mL of Tryptic soy broth (TSB; Difco, USA) at 37 ℃ for 18 hrs to obtain working culture. The final concentration was adjusted to 7.00 Log_{10} CFU mL^{-1} for high level contamination and 4.00 Log_{10} CFU mL^{-1} for low level contamination. The artificial contamination was performed by soaking method under control atmosphers in a biological safety cabinet class 11 (AstecMicroflow, Bioqell, UK)

UV-C treatment

UV-C lamp (280 nm, 16 W) was used for decontamination treatments. In this study the UV-C radiation process was performed as Water Assist System (WAS). The WAS demonstrated in the Table 1. In dynamic systems, water was circulated by pumps as 1.5 L min^{-1}. All of systems used 6 L sterile water as medium and UV-C lamps were warmed around 30 min. before use. Decontamination process was conducted in 20×30×25 cm as presented in Figure 1. stanless steel box. The intensity of UV-C was 3.20, 6.40, 9.60 and 12.80 kW/m^3. Radish sprouts samples were soaked and 10-grams of sample were withdrawn at 0, 5, 10, 15, 20 and 30 min. intervial time. The population of remaining *S. Typhimurium* ATCC 13311 was determined by spread plate technique using Eosin methylene blue agar plus 2% NaCl (EMB; Difco, USA). Plates were incubated at 37 ℃ for 24 h. The populations of such microorganisms were reported as Log_{10} CFU g^{-1}. The effect of temperature on WAS UV-C radiation process was also determined at 10 ℃.

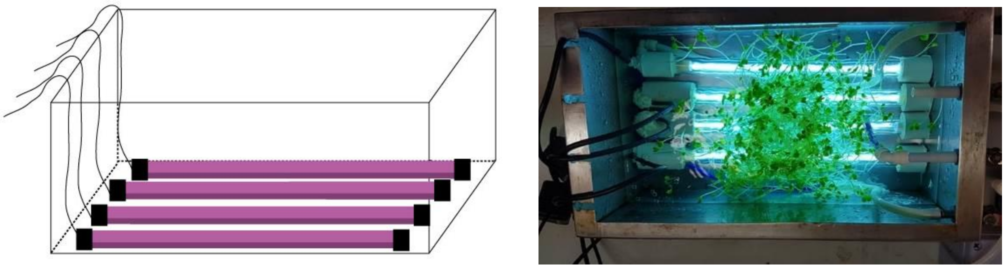

Figure 1. The WAS UV-C radiation process

Reduction Kinetic

The reduction rate (k) was calculated follows by equation 1.

$$\ln \frac{N_t}{N_0} = -kt \qquad \textbf{(1)}$$

where:

$\ln N_t$	: Population of microorganism at t (ln CFU g^{-1})
$\ln N_0$	: Populationof microorganism at 0 min (ln CFU g^{-1})
t	: Tim (min)
k	: Kinetic reduction (ln CFU $g^{-1}.min^{-1}$)

Statisticc analysis

All of treatments were done in triplicate. Analysis of variance (ANOVA) and the Duncan's test were performed using Statistical Package for the Social Sciences (SPSS) version with statisticl significance set at $p \leq 0.05$.

Results

Effect of Dynamics WAS UV-C radiation process on the decontamination of S. Typhimurium of Radish Sprouts

The effect of WAS UV-C radiation process in dynamic systems against low level contaminated *S.* Typhimurium ATCC 13311 on Radish sprouts using fresh water and reused water was presented in Figure 2. The WAS UV-C radiation process reduced the population of *S.* Typhimurium ATCC 13311 contaminated with Radish sprouts to 0.03, 0.07, 0.11, and

0.13 Log10 CFU g-1 for 30 minutes at UV-C intensities of 3.20, 6.40, 9.60, and 12.8 kW m^{-3}, results showed that the WAS UV-C radiation system reduced *S*. Typhimurium as 0.04, 0.09, 0.09 and 0.11 Log_{10} CFU g^{-1} at intensities of UV-C of 3.20, 6.40, 9.60 and 12.8 kW m^{-3} for 30 min. respectively. The highest UV-C intensity, at 12.8 kW m^{-3}, presented the highest effect of decontamination compared with the other intensities.

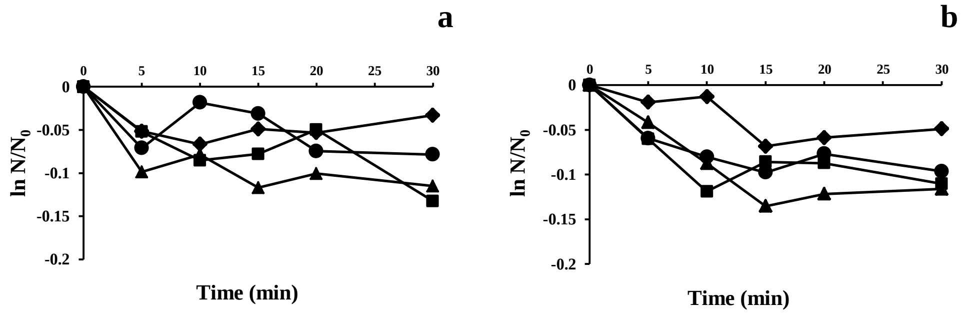

Figure 2. Reduction numbers of *S*. Typhimurium ATCC 13311 contaminated on Radish sprouts at low level contamination in different conditions of WAS UV-C radiation process in dynamic system with different source of water (a; fresh water and b; reused water) at different intensity of UV-C (♦ = 3.2 kW m^{-3}, ■ = 6.4 kW m^{-3}, ● = 9.6 kW m^{-3} and ▲ = 12.8 kW m^{-3})

The effect of WAS UV-C radiation in high-level condition treatments was presented in Figure 3, and the results were similar to those previously published. Figure 3a displayed treatment when using sterile water. At 3.20 kW m^{-3}, the effect can reduce the population of *S*. Typhimurium by around 0.08 Log_{10} CFU g^{-1} for 30 min, respectively. The highest population of *S*. Typhimurium was decontaminated by UV-C at 6.40 kW m^{-3}, which was 0.14 Log_{10} CFU g^{-1} for 30 min. of contact time. At 9.60 kW m^{-3}, it could reduce the population of *S*. Typhimurium around 0.08 Log_{10} CFU g^{-1} for 30 min, respectively. The highest intensity, 12.8 kW m^{-3}, had a greater effect on decontamination than lower intensities. This result showed the ability of decontamination when increasing the intensity of UV-C. This intensity decontaminated *S*. Typhimurium around 0.15 Log_{10} CFU g^{-1} in 30 mins. The effect of WAS UV-C radiation to decontaminate the population of *S*. Typhimurium on Radish sprouts at reused water treatment was shown in Figure 3b. The effect of UV-C was similar in the previous result. The intensity of UV-C at 3.20 kW m^{-3} firmly decontaminated the population of *S*. Typhimurium as 0.04 Log_{10} CFU g^{-1} for 0.00 to 30.00 min. At 6.40 kW m^{-3}, the reduced population was 0.06 Log_{10} CFU g^{-1} for 30.00 min, respectively. Then, when the intensity of UV-C was increased to 9.60 kW m^{-3}, the result was an increase in the effect of decontamination. The population of *S*. Typhimurium was reduced by UV-C was 0.00 to 0.11 Log_{10} CFU g^{-1} for 30 mins. In addition, the highest intensity also showed the highest ability for decontamination. The 12.8 kW m^{-3} decontaminated around 0.15 Log_{10} CFU g-^{1} in 30 min.

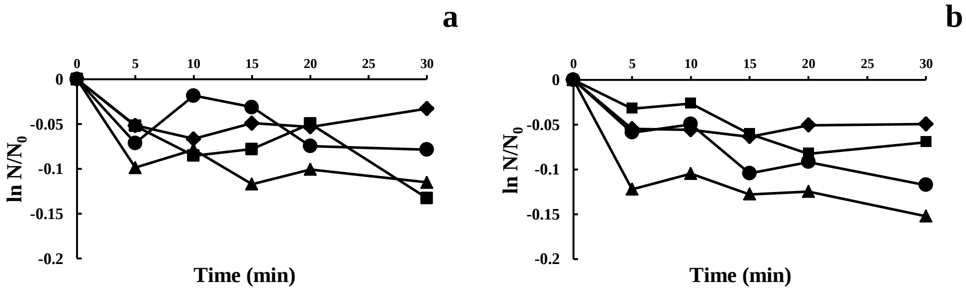

Figure 3. Reduction numbers of *S*. Typhimurium ATCC 13311 contaminated on Radish sprouts at high level contamination in different conditions of WAS UV-C radiation process in dynamic system with different source of water (a; fresh water and b; reused water) at different intensity of UV-C (♦ = 3.2 kW.m^{-3}, ■ = 6.4 kW.m^{-3}, ● = 9.6 kW.m^{-3} and ▲ = 12.8 kW m^{-3})

Effect of Static WAS UV-C radiation process on the decontamination of S. Typhimurium of Radish Sprouts

Firstly, the effect of WAS UV-C radiation on decontaminating the population of *S*. Typhimurium on Radish sprouts at a low level of contamination in fresh water and continuous water was demonstrated in Figure 4. Fresh water treatments were shown in Figure 4a. The trends used a similar method. When the intensity of UV-C increased, the decontamination effect was increased. At 3.20 kW m^{-3} of intensity, the population of *S*. Typhimurium was decreased by around 0.05 to 0.07 Log_{10} CFU g^{-1} for 5 to 30 min, respectively. Likewise, at 6.40 kW m^{-3}, the population of *S*. Typhimurium was 0.08 Log_{10} CFU g^{-1} for 30 min. However, the higher intensity of UV-C showed a better effect than lower intensities. For 9.60 kW m^{-3} decontaminated, the population of *S*. Typhimurium was 0.15 Log_{10} CFU g^{-1} for 30 min of the method. When UV-C at the intensity of 12.80 kW m^{-3} was applied, the population was reduced around 0, 0.04, 0.03, 0.05, 0.12 and 0.13 Log_{10} CFU g^{-1} for 0, 5, 10, 15, 20 and 30 min, respectively. Figure 4b presented the reused water treatment. The method demonstrated good efficacy in decontaminating the population of *S*. Typhimurium on Radish sprouts at high UV-C intensity, consistent with previously reported results. However, the low intensity showed the fluctuating effect of decontamination. The highest effect of decontamination was 0.13 Log_{10} CFU g^{-1} for 30 min when using intensity at 12.80 kW m^{-3}.

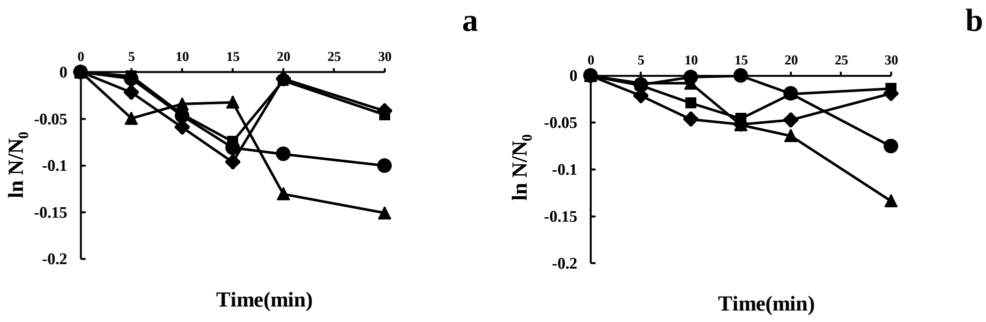

Figure 4. Reduction numbers of *S.* Typhimurium ATCC 13311 contaminated on Radish sprouts at low level contamination in different conditions of WAS UV-C radiation process in static system with different source of water (a; fresh water and b; reused water) at different intensity of UV-C (♦ = 3.2 kW m^{-3}, ■ = 6.4 kW m^{-3}, ● = 9.6 kW m^{-3} and ▲ = 12.8 kW m^{-3})

Secondly, the effect of WAS UV-C radiation on decontaminating the high-level contamination of *S.* Typhimurium on Radish sprouts was shown in Figure 5. The population of *S.* Typhimurium was steadily decontaminated around 0.02 Log10 CFU g^{-1} for 0 to 30 min when using intensity at 3.20 and 6.40 kW m^{-3}. At 9.60 kW m^{-3} of intensity, this could reduce the population by 0.08 Log10 CFU/g1 for 30 min. At the highest level of intensity, at 12.8 kW m^{-3}, this intensity had the highest effect of decontamination the population of *S*. Typhimurium on Radish sprouts, and the result showed that when time was increased, the effect increased. At 12.80 kW m^{-3}, the population was reduced by 0.04 to 0.15 Log10 CFUg^{-1} for 0 min, especially to 30 min. In the reuse water treatment, the effect of WAS UV-C on decontaminating the population of *S.* Typhimurium was corresponding to previous results. The UV-C intensity showed the efficiency of decontaminating on the population of *S*. Typhimurium especially at the highest intensity of 12.8 kW m^{-3}. In addition, the time of treatment was also related to this effect. The highest effect was 0.15 Log10 CFU g^{-1} at 30 mins at 12.8 kW m^{-3}.

Kinetic reduction of S. Typhimurium on Radish sprouts

The kinetic reduction (k-value) was explained in term of the rate of decontamination. Kinetic reduction was calculated by slop of kinetic equation. The kinetic reduction in dynamic water system which could divide to each condition as shown in Table 2. In the first path presented low level of contamination in sterile water and continuous water. In sterile water condition, the kinetic reduction was 7.0×10^{-4}, 2.0×10^{-4}, 3.0×10^{-4} and 1.2×10^{-3} ln CFU g^{-1}.min^{-1} at 3.20, 6.40, 9.60 and 12.8 kW m^{-3}, respectively. In continuous water condition, the trend of result showed similar to previous results. It was around 2.0×10^{-3} to 5.0×10^{-3} at 3.20, 6.40 and 9.60 kW m^{-3}.

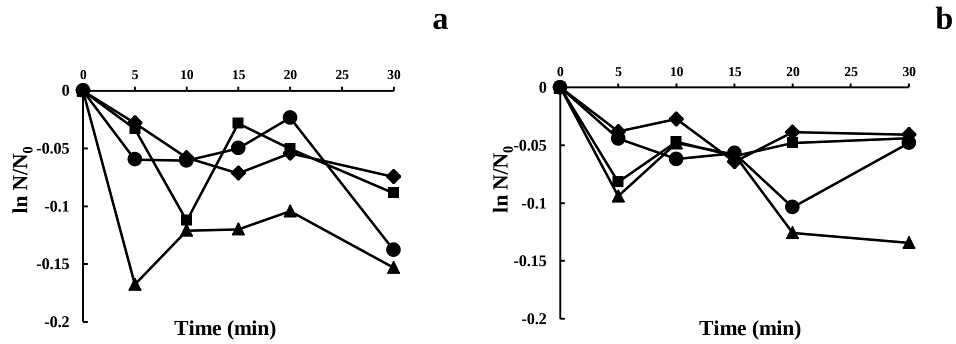

Figure 5. Reduction numbers of *S.* Typhimurium ATCC 13311 contaminated on Radish sprouts at high level contamination in different conditions of WAS UV-C radiation process in static system with different source of water (a; fresh water and b; reused water) at different intensity of UV-C (♦ = 3.2 kW m^{-3}, ■ = 6.4 kW m^{-3}, ● = 9.6 kW m^{-3} and ▲ = 12.8 kW m^{-3})

Table 2. Kinetic reduction (k) of UV-C intensity in dynamic water system at different level of contamination on Radish sprouts

Level of contamination	Water conditions	UV intensity (kW m^{-3})	Linear equation (y = ax+c)	k ($\times 10^{-3}$ ln CFU $g^{-1}.min^{-1}$)	R^2
Low	Sterile	3.20	-0.0004x + 0.0214	0.04^{b}	.0800
		6.40	-0.0027x + 0.0571	2.70^{a}	.3492
		9.60	-0.0006x + 0.0421	0.06^{b}	.0441
		12.80	-0.0012x + 0.0066	1.20^{a}	.2519
	Continuous	3.2	-0.0015x - 0.0457	1.50^{cd}	.1377
		6.4	-0.0028x - 0.0200	2.80^{c}	.1533
		9.6	-0.0048x + 0.0362	4.80^{b}	.3195
		12.8	-0.0095x - 0.0896	9.50^{a}	.6565
High	Sterile	3.2	-0.0042x - 0.0499	4.20^{b}	.5383
		6.4	-0.0069x - 0.0247	6.90^{a}	.7337
		9.6	-0.0044x - 0.0101	4.40^{b}	.3917
		12.8	-0.0067x - 0.0278	6.70^{a}	.4863
	Continuous	3.2	-0.0023x + 0.0076	2.60^{cd}	.7675
		6.4	-0.001x + 0.03170	3.50^{c}	.1908
		9.6	-0.0017x + 0.0350	6.00^{b}	.4567
		12.8	-0.0006x + 0.0424	10.00^{a}	.0282

[a,b,c,d] show in different of kinetic reduction when under different conditions (p≤0.05)

The kinetic reduction of static systems. Kinetic reduction of sterile conditions was shown in first path (Table 3). At low level of contamination on Radish sprouts, the kinetic reduction was 2.1×10^{3} ln CFU $g^{-1}.min^{-1}$ at 12.8 kW/m^{-3}. It's highest than other intensity in this condition. However, in continuous water treatment shown the efficiency of reduction than sterile water treatment causes higher kinetic reduction than previously condition. In this condition was 4.2×10^{-3} ln CFU $g^{-1}.min^{-1}$ when using 12.8 kW/m^{-3} of UV-C intensity. Moreover, kinetic reduction value in this study was investigated when increasing intensity of UV-C resulted to also increased kinetic reduction value. Likewise, in high contamination level on Radish sprouts, kinetic value increased when using highest intensity of UV-C. At 12.8 kW/$m^{-3}$of intensity was highest kinetic reduction as $4.3\text{x}10^{-3}$ ln CFU g^{-1} min^{-1}

The kinetic reduction of contamination inside radish sprouts was presented in the Table 4. The result of static system was not different to dynamic system and trend of kinetic reduction also similar. So, in contamination inside the Radish sprouts had affected decontamination the population of *S*. Typhimurium. The highest of kinetic reduction at 12.8 kW/m^{3} in sterile water condition at static system was 3.90×10^{-3} ln CFU/g^{1}.min^{1}.

Table 3. Kinetic reduction (k) of UV-C intensity in static water system at different level of contamination on Radish sprouts

Level of contamination	**Water conditions**	**UV intensity (kW m^{-3})**	**Linear equation (y=ax+c)**	**k ($\times10^{-3}$ ln CFU g^{-1} min^{-1})**	**R^2**
Low	Sterile	3.20	-0.0003x - 0.0420	0.30^{c}	.0134
		6.40	-0.0012x - 0.0132	1.20^{b}	.5823
		9.60	-0.0001x - 0.0224	0.10^{c}	.0029
		12.80	-0.0021x - 0.0530	2.10^{a}	.2757
	Continuous	3.2	0.0005x + 0.0384	-0.05^{c}	.0325
		6.4	0.0043x + 0.0454	-4.30^{d}	.3576
		9.6	-0.0026x + 0.0017	2.60^{b}	.7769
		12.8	-0.0042x + 0.0115	4.20^{a}	.4523
High	Sterile	3.2	-0.0032x - 0.0008	3.20^{b}	.8249
		6.4	-0.0003x - 0.009	0.30^{c}	.0036
		9.6	-0.0004x + 0.0227	0.40^{c}	.0105
		12.8	-0.0090x + 0.0312	9.00^{a}	.1294
	Continuous	3.2	-0.0017x + 0.0089	1.70^{ab}	.3706
		6.4	-0.0003x- 0.0230	0.30^{b}	.0004
		9.6	-0.0003x - 0.0009	0.30^{b}	.1153
		12.8	-0.0021x + 0.0068	2.10^{a}	.7208

[a,b,c,d] show in different of kinetic reduction when under different conditions ($p\leq0.05$)

Table 4. Kinetic reduction (k) of contamination of S. Typhimurium inside Radish sprouts

Water System	Water conditions	UV intensity ($kW\ m^{-3}$)	Linear equation (y=ax+c)	k ($\times 10^{-3}$ ln CFU g^{-1} min^{-1})	R^2
Dynamic	Sterile	3.20	-0.003x - 0.0069	$3.00^{a} \pm 2.73$	.8230
		6.40	-0.0006x - 0.0222	$0.60^{a} \pm 1.05$	.1168
		9.60	-0.0002x - 0.0253	$0.20^{a} \pm 1.73$	.0064
		12.80	-0.0015x - 0.0183	$1.50^{a} \pm 0.75$	.2008
	Continuous	3.2	-0.0003x - 0.073	$0.30^{ab} \pm 2.79$	.0038
		6.4	-0.0029x - 0.0328	$2.90^{a} \pm 1.05$	.1331
		9.6	0.0014x - 0.0668	$-1.40^{b} \pm 0.55$	.0527
		12.8	-0.0029x - 0.0136	$2.90^{a} \pm 0.75$	.7674
Static	Sterile	3.2	-0.0002x - 0.0028	$0.20^{ab} \pm 0.68$	.0058
		6.4	-0.0009x + 0.0042	$0.90^{a}b \pm 2.89$	.2174
		9.6	0.0007x - 0.0592	$-0.70^{b} \pm 0.60$	.0333
		12.8	-0.0039x - 0.0212	$3.90^{a} \pm 2.36$	.838
	Continuous	3.2	-0.0026x - 0.0083	$2.60^{a} \pm 1.70$	.7396
		6.4	-0.0009x - 0.0068	$0.90^{a} \pm 0.35$	.3274
		9.6	-0.0008x - 0.0066	$0.80^{a} \pm 0.55$	.4677
		12.8	-0.001x + 0.0054	$1.00^{a} \pm 0.68$	.6656

[a,b,c,d] show in different of kinetic reduction when under different conditions ($p \leq 0.05$)

Effect of UV-C under low temperature to decontamination S. Typhimurium contamination on Radish sprouts

The decontamination effect of UV-C under low temperature at 10 ℃ was shown in Figure 6. Three level of contamination (high level contamination, low level contamination and inside contamination on Radish sprouts) showed the highest effect to decontamination at highest intensity of UV-C.

In low level contamination (Figure 8a), the population of *S*. Typhimurium was decontaminated at 12.8 kW m^{-3} around 0.04, 0.09, 0.11, 0.10 and 0.15 Log_{10} CFU g^{-1} for 5, 10, 15, 20 and 30 min, respectively. High level contamination of *S*. Typhimurium (Figure 8b), the UV-C presented the reduced at 5 min as 0.09 Log_{10} CFU g^{-1} and then rose to 0.08 Log_{10} CFU g^{-1} at 10 mins until dramatically increased to 0.15 Log_{10} CFU g^{-1} for 30 min. For inside contamination, UV-C decontaminated the population of *S*. Typihmurim as 0.05 and 0.07 Log_{10} CFU g^{-1} for 20 and 30 min, respectively. The kinetic reduction was shown in Table 5. In tree level of contamination on Radish sprouts, k-value also increased when using highest intensity of UV-C. It was around 4.0×10^{-3} and 0.2×10^{-3} ln CFU $g^{-1}.min^{-1}$ in low contamination level, high contamination level and inside contamination respectively.

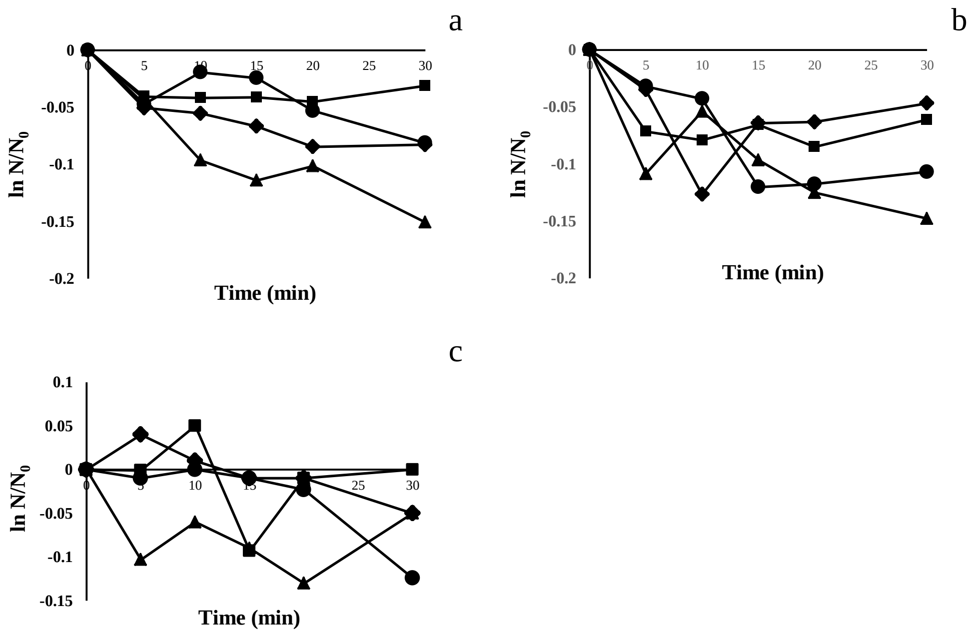

Figure 6. The effect of decontamination *S*. Typhimurium on Radish sprouts at low temperature in different level of contamination by (a; low level of contamination, b; high level of contamination and c; inside contamination) when using different intensity of UV-C (♦ = 3.2 kW m^{-3}, ■ = 6.4 kW m^{-3}, ● = 9.6 kW m^{-3} and ▲ = 12.8 kW m^{-3})

Discussion

In this study, the effect of UV-C radiation in dynamic WAS UV-C radiation process was able to reduce the population of *Salmonella* Typhimurium ATCC 13311 at different level of contaminated on radish sprouts. Kim *et al.* (2013) showed the result of UV radiation at 6.80 mW.cm^{-2} could reduce the population of *Salmonella* Typhimurium ATCC 13311 contaminated on lettuce than used the UV radiation at 1.36, 2.72 and 4.08 mW.cm^{-2}. According to this experiment, when high UV-C radiation at intensity 12.8 kW.m^{-3} was applied, the result indicated that the effect to reduce microorganism was greater than lower UV-C radiation at both level of contamination. In addition, *Salmonella* Typhimurium ATCC 13311 contaminated on Radish sprout on surface (cotyledon and stem) caused the UV-C resulted in high efficiency to eliminated *Salmonella* Typhimurium ATCC 13311 on surface (Butot *et al.*, 2018). In case of the studied on kinetic reduction, UV-C radiation demonstrated such kinetic against *Salmonella* Typhimurium ATCC 13311 similarly at different condition. This phenomenon was caused by the characteristics of contamination on Radish sprout spread to around of the part of sprout, rough surface and many pore (Warriner *et al.,* 2003). For this reason, it was noticed that the effect of UV-C radiation was decreased. Thus, the effect of UV-C radiation under low temperature to reduce the population of *Salmonella* Typhimurium ATCC 13311 presented similar trend to reduce the microorganism at room temperature. Heat combination with UV-C radiation were alternatively increased the effect of UV-C radiation (Gouma *et al.*, 2015). However, low the process of UV-C radiation under low temperature could control the temperature of water so there are prevent the appearance of the sprout including freshness of the sprouts and vegetable salad.

In this experiment, the results of the study indicated the similar result when used the UV-C radiation at different condition (under water, dynamic and static system). According to the previous esearch of Selma *et al.* (2008), the reduction of mesophile bacteria, coliform and yeast contaminated on raw onion by UV-C radiation at around 2.80 and 1.95 Log_{10} CFU g^{-1} was report. In addition, the UV-C radiation also reduced *Salmonella* sp. contaminated on tomatoes and lettuce (Guo *et al.,* 2017). Therefore, the UV-C radiation under different condition could eliminate the microorganism on fresh sprout (Gardner and Shama, 2000). The high intensity UV-C radiation demonstrated the effect on the reduction of the microorganism more than at low intensity UV-C radiation. However, the long contact time of UV-C radiation presented high effect on the reduction of *Salmonella* Typhimurium ATCC 13311. Kim *et al.* (2013) reported that the population of *Escherichia coli*, *Salmonella* Typhimurium and *Listeria monocytogenes* contaminated on lettuce was reduced by the UV-C radiation at 6.80 $W.m^{-2}$ in 10 min for around 5.00 Log_{10} CFU g^{-1}. However, in this experiment, the UV-C radiation at 12.8 $kW.m^{-3}$ was presented higher effect to destroy *Salmonella* Typhimurium ATCC 13311 in 30 min at all of condition. This phenomenon can be described as that is because of the lower penetration of UV-C, the reduction efficiency on surface of Radish sprouts was noticeably decreased. It was It is the same with previous experiment and explanations of Escalona *et al*. (2010). The UV-C radiation at 12.8 $kW.m^{-3}$ presented the effect of reduction *Salmonella* Typhimurium ATCC 13311 statistically significant ($p \leq 0.05$). From the observation of this experimental results, it could be indicated that Time dependent and Intensity dependent become the factors related to the efficiency of UV-C radiation process. Thus, the higher UV-C radiation demonstrated effect to eliminate the population of *Salmonella* Typhimurium ATCC 13311 than the lower UV-C radiation (Stermer *et al.*, 1987).

It concluded that the effect of decontamination in term of kinetic reduction of UV-C is decontaminated the *S*. Typhimuriun contaminated on Radish sprouts. Kinetic reduction related in log reduction per times. The intensity of UV-C presented the potential to decontaminat *S*. Typhimurium on Radish sprouts. The highest effect of decontamination was shown in intensity at 12.8 $kW.m^{-3}$ which also showed higher kinetic reduction than other intensity. When the intensity of UV-C increased the effect of decontamination on Radish sprouts was increased. UV-C radiation could prevent recontamination and crosscontamination of sprouts. This alternated non-thermal process for the application in fresh sprouts products to prevent the contaminaion of foodborne bacteria and enhanced the safety and quality of products.

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