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Postharvest Treatment of Chinese Kale (*Brassica oleracea* var. *alboglabra*) by Pulse Light to Removal of Microbial Load, Pesticide Residue and Integrity of Physicochemical Quality and Phytochemical Constituent

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Abstract

Existence of microorganisms, pesticide residue on fresh vegetables has a potential hazard to human health. The demand for safe green Chinese kale (*Brassica oleracea* var. *alboglabra*) has increased recently. Chinese kale is a healthy botanical attached to the Brassicaceae class. It contains numerous nutritional and phytochemical constituents beneficial for human health. Besides health benefits, this green vegetable also poses food safety concerns due to pathogen and pesticide residue during cultivation. Non-thermal physical technology like pulsed light (PL) will be a promising alternative to eradicate microbial and pesticide residue while preserving the best physicochemical properties and phytochemical components.This research evaluated the influence of different pulsed light intensities (1.2-10.8 J/cm^2) on the removal of microbial load and pesticide residue as well as weight attrition, texture hardness, dry matter, vitamin C, total phenolic content in the treated Chinese kale. Results showed that pulsed light intensity 8.4 J/cm^2 was appropriate to completely eliminate pathogenic bacteria such as *Escherichia coli, Staphylococcus aureus, Salmonella*; pesticide substances such as carbendazim, abamectin, cypermethrin, chlorpyrifos ethyl, mancozeb. At pulsed light intensity 8.4 J/cm^2, weight attrition in the treated sample was lower than weight attrition in the untreated; meanwhile textural hardness, dry matter, ascorbic acid and total phenolic content remained higher in the the treated sample compared to the untreated. The results reveals that the pulsed light technique should be applied as a promising decontamination approach for removal of the pathogen as well as pesticide residue with minor impact on physicochemical properties and phytochemical constituents.

Keywords: Chinese kale, microorganism, pesticide, physicochemical, phytochemical, pulsed light intensity

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INTRODUCTION

Chinese kale (*Brassica oleracea* var. *alboglabra*) contains abundant bioactive antioxidants and anticarcinogenic constituents such as sugar, organic acid, beta-caroten, ascorbic acid, glucosinolate, amino acid, phenolic and flavonoid contributing to human health.[1-3] Ascorbic acid poses as a powerful antioxidant, an enzyme cofactor, a cell-signalling regulator in different vital physiological reactions.[4] Glucosinolate successfully protect human against cancer.[5-6] Phenolics contribute to health-supporting advantages, including anti-oxidant, anti-inflammatory, anti-microbial, anti-allergic and anti-carcinogenic properties.[7] Chinese kale is utilized for its stems as edible segments, and the soft leaves are popularly eaten as a leafy vegetable.[8] Apart from nutritional and therapeutic functions, Chinese kale exhibits food safety concerns relating to pathogenic microorganisms and pesticide residues by farmers during crop production. Microbial hazards are commonly originated from agricultural environment like poluted water ad contaminated soil. Meanwhile chemical hazards like pesticides are mostly derived from pesticide abuse in pest control without following withdrawal time in postharvest. Food-borne illnesses were associated to the consumption of contaminated fruits and vegetables originated from pesticide residues or pathogenic microorganisms. Common pathogenic microorganisms posed the most critical risks like *Salmonella, Escherichia coli*, and *Listeria monocytogenes*. Deposition of pesticide residues like carbendazim, abamectin, cypermethrin, chlorpyrifos ethyl, mancozeb on the surface of agricultural products induced to the serious health hazards like cancer, child defect, and neuroevolved turmoil.[9] Innnovative food safety interventions effectively suppressed germ epidemic and pesticide related dysfunctions.[10]

The postharvest washing step and sanitizer were necessary to partially eliminate field-acquired contamination.[11] However both washing and sanitizer encountered some disadvantages. Numerous innovative non-thermal methods such as ozone, ultrasound, cold plasma, high hydrostatic pressure, dense phase carbon dioxide, pulsed light were proposed for the removal of microorganisms and pesticides.[12] Pulsed light (PL) was highly evaluated as an ideal non-thermal treatment for food decontamination.[13] There was no need of washing, heating or chemical residual hazard while maintaining texture, color, nutritional proximate and organoleptic properties.[14] This cost-effective technology ensured the hygienic safety as well as the prolonged stability of treated products without any residue left.[15] Food and Drug Administration (FDA) approved pulsed light at dose up to 12 J/cm^2 in fruit and vegetable processing.[16] The main mechanism of pulsed light operated on the acceleration of high discharge voltage. The saving energy was released in hyper-brief pulses via a mild beam of xenon flash.[17,18] Xenon gas is more environment-friendly than ultraviolet as it didn't apply mercury[19]. This xenon beamed a wide spectrum light flash about 25% in the ultraviolet extent.[20] Effectiveness of pulsed light depened on following criteria: intensity, time, pulsed count, pulsed width, frequency and peak energy.[21] Pathogen inactivation caused by irreversible rupture of cell.[22,23] DNA mutation and impaired replication were found in microorganisms exposing to pulsed light.[24] Microbial attrition under pulsed light treatment was highly variable owing to cavities in surface microstructure to create better shading effect for pathogenic survival[11]. Cauliflower having coarse skin was low sanitized by pulsed light than else plants due to the protecting validity.[25] Pulse light prolonged the wholesomeness and built up economic value of food during handling and distribution.[26] Several notable researches mentioned to the utilization of PL exposure on agricultural products. The changes in the quality attributes of inoculated spinach after PL treatment and after storage were verified.[24] After PL treatment at 8–120 kJ/m^2, the inoculum on the surface of the spinach presented 1.72-2.60 log reductions, and the gas composition, color modification, and antioxidant capacity all indicated an improved quality.[27] Under PL treatment with lamp DC voltage of 1800–4200 V, pulse width of 0.5–1.0 ms, frequency of 2 Hz, and treatment time of 1–5 min, there were no significant differences between the control and PL-treated samples of ground black pepper, red pepper, embryo buds of rice, and sesame seed in respect of color, water activity, and moisture content.[28]

Besides benefits, pulsed light also had limitations of sample exposure due to longer exposing duration, which might cause thermal

inactivation of microbes. Accelerated temperature by longer PL treatments induced to an additional impact on microbial inactivation depending on the substrate characteristics.[29-30] PL treatment had to satisfy an equilibrium between utilizing effective non-thermal exposure and retaining fresh-like foodstuff attributes as noticeable by facilities of modifications in structure, pigment, nutritional proximate or organoleptic characteristics.[14,20] PL-treated products encountered restricted preference by the consumers due to following reasons. The first disadvantage was that the mechanism of this method had not yet thoroughly presented to buyers because they needed clear information towards the items they purchased. Next, PL-treated items were commonly labeled as "minimally processed foods" that implicated not good impression in the sense of buyers that the category was not well-treated and might exhibit potential health concerns after using.[31]

Fruits and vegetables rich in sugars but inferior in lipids and proteins were more suitable for pulsed light treatment.[27] Purpose of this research aimed to evaluate the effect of pulsed light treatment at different intensity to the possibility of microbial and pesticide residue removal as well as retention of physicochemical quality and phytochemical component during storage.

MATERIAL AND METHOD

Material

Chinese kale leaves were collected on Thu Duc market, Ho Chi Minh city, Vietnam. A mini-scale pulsed light system was designed for experiments. This system included power supply, cooling blower, xenon lamp and chamber. The present study also utilized gas chromatography-mass spectrometer to determine pesticide residue; stomacher, vortex, incubator, colony counter and 3M-Petrifilm plates to enumerate aerobic plate count, *coliform, Escherichia coli, Staphylococcus aureus, Salmonella*; digital weight balance to estimate weight attrition; texture penetrator to measure textural hardness; hand-held refractometer to determine dry matter; biuret for visual titration; UV-Vis spectrophotometer to measure total phenolic content. Chemical subtances were all pure grade.

Studying method

Pulsed light system set at temperature 25±0.5°C, voltage 2600 V, treatment time 3 minutes. Intensity of xenon lamp emitted at 1.2, 3.6, 6.0, 8.4, 10.8 J/cm^2. Fresh leaf without treatment was used as control. Both the untreated and treated samples were taken to measure microbial load of aerobic plate count, coliform, *Escherichia coli, Staphylococcus aureus, Salmonella*; pesticide residue of carbendazim, abamectin, cypermethrin, chlorpyrifos ethyl, mancozeb. The untreated and treated samples were packed in plastic pouch and kept at 4°C for 10 days. In 2 day-interval, samples were taken to evaluate weight attrition, textural hardness, dry matter, vitamin C, total phenolic content.

Microbial parameters such as aerobic plate count, coliform, *Escherichia coli, Staphylococcus aureus, Salmonella* were enumerated following 3M-Petrifilm protocols. Pesticide residues such as carbendazim, abamectin, cypermethrin, chlorpyrifos ethyl, mancozeb were quantified by gas chromatography-mass spectrometry. Weight attrition (%) was defined as the difference of weight at the beginning and the time of interval sampling. Leaf textural hardness (N) was measured by texture penetrator. Dry matter (oBrix) was determined through refractometer. Vitamin C (mg/100g) was quantified by volumetric method using a 2,6-dichlorophenol indophenol visual titration described by AOAC.[32] Total phenolic (mg GAE/100g) was estimated by Folin-Ciocalteu reagent assay.[33]

Statistical analysis

The demonstrations were established in 3 replications with various sets of samples. The Fig. was illustrated as mean±standard deviation. Statistical summary was done by the Statgraphics Centurion version XVI.

RESULT AND DISCUSSION

Effect of pulsed light intensity to microbial load on Chinese kale was clearly presented in Table 1. Increasing pulsed light intensity resulted to less microbial load. The highest microbial load was recorded on the untreated samples, meanwhile the lowest microbial load was found on the samples treated by pulsed light intensity over 8.4 J/cm^2. Pathogens of *Escherichia coli, Staphylococcus*

Table 1. Microbial density (log CFU/g) on Chinese kale affected by pulsed light intensity (J/cm^2)

Microbial density (log CFU/g)	Pulsed light intensity (J/cm^2)					
	0	1.2	3.6	6.0	8.4	10.8
Aerobic plate count	9.28±0.13^{a}	6.19±0.18^{b}	5.38±0.11^{bc}	4.52±0.14^{c}	3.71±0.10^{cd}	2.90±0.08^{d}
Coliform	5.17±0.06^{a}	3.41±0.05^{b}	3.03±0.03^{bc}	2.47±0.07^{c}	2.01±0.02^{cd}	1.60±0.04^{d}
Escherichia coli	3.75±0.02^{a}	2.39±0.03^{b}	1.07±0.05^{bc}	0.18±0.03^{c}	0^{d}	0^{d}
Staphylococcus aureus	3.59±0.01^{a}	2.06±0.02^{b}	0.83±0.00^{bc}	0.07±0.01^{c}	0^{d}	0^{d}
Salmonella	2.67±0.03^{a}	1.35±0.01^{ab}	0.24±0.02^{b}	0^{c}	0^{c}	0^{c}

Numbers are the average of triplicate; characters in row followed by the same figure/s are not significant difference (α = P=0.05).

aureus, Salmonella were completely inhibited at pulsed light intensity 8.4 J/cm^2. The susceptibility to pulsed light is listed to be Gram[-] microbes > Gram[+] microbes > microbial spore > fungal spore.[21,34,35] Bacteria was more suceptible to pulsed light compared to virus.[36] Vegetative cells were less stable to spores under pulsed light.[35,37,38] Spores had better resistance than botanical tissues owing to their thickened external and internal layers being constituted from protein and peptidoglycan membrane.[39,40] Accelerating pulsed light intensity induced in pulsed light-mediated lethality via a multi-injury cellular process.[22] *Escherichia coli* load on pennywort leaf was significantly inhibited by 6.9 J/cm² of pulsed light.[41] *Campylobacter* and *Salmonella* were greatly decontaminated by pulsed light.[20] 2.4 log CFU attrition of *L. monocytogenes* was noticed at 17.2 J/cm^2 of pulsed light treatment on solid media.[42] 1 log CFU decrease of *Escherichia coli* and *L Candida albicans. monocytogenes* was found on salmon fillet treated by 5.6 J/cm^2 of pulsed light.[26] Pathogenic inactivation on cantaloupe and berry was quitely limited to 1 log CFU at 12 kJ/m^2 pulsed light intensity.[43] Microbial eliminations of 0.45, 0.66, and 0.88 log CFU/mL for fine black pepper, red pepper, and rice sprout, correspondingly were found by 12.31 J/cm^2 pulsed light intensity wherein over 3 log attritions were noticed on sesame seed at 11.26 J/cm^2 pulsed light intensity.[28] 5 log attrition of *Escherichia coli* in hydrogen at 10 mJ/cm^2 of pulsed light was noticed.[44] Pulsed light at intensity 26.25 J/cm^2 induced to 3.2 log attrition in the aerobic plate count in raw milk.[45] *Escherichia coli* was eliminated by over 4.7 log CFU/ml in apple juice supposed with pulsed light at 28 J/cm^2 intensity.[46] Pulsed light induced significantly lower total aerobic plate count in 14-day preservation versus the untreated apple.[47] Microbial inactivation was originated from irreparable alterations of treated DNA molecules, cytoplasm contraction, damage of the inner structure inducing to release of cytoplasmic composition and cell fatality.[48-49] Pulsed light invaded into cell of microorganism causing irreversible protein denaturation as mentioned in *Candida albicans*[22] and *Saccharomyces cerevisiae*.[23] Pulsed light at high intensity produced reactive oxygen species indirectly affecting to cellular and molecular integrity.[21] Different studies reported the inactivation of aerobic plate count, yeast, mold, *Escherichia coli*, *Listeria*, and *Salmonella* under pulsed light treatment.[29,50] Pulsed light caused textural modifications in intact membrane of *Escherichia coli*, resulting to smoothening of cells.[51] *Salmonella* was not able to fix the cell vulnerability caused by pulsed light via photoreactivation principle.[52] Matrix properties such as nutritional proximate, dry matter, acidity and light absorbance greatly affected to microbial attritions.[29,30,53] Under PL treatment with lamp DC voltage of 1800–4200 V, pulse width of 0.5–1.0 ms, frequency of 2 Hz, and treatment time of 1–5 min, there were eliminations of 0.45, 0.66, and 0.88 log CFU/mL for ground black pepper, red pepper, and embryo buds of rice, respectively, under 12.31 J/cm^2 of a total energy fluence. Meanwhile, >3-log inactivations were noticed on sesame seed under 11.26 J/cm^2 of a total energy fluence.[28]

Hot weather temperature and high relative humidity in tropical region like Vietnam created favorable conditions for insect and disease proliferation. Farmers commonly mixed different pesticides together to spray on their crops. These chemical reagents were used at high frequency, excess of recommendation on label specification. Moreover they did not follow

Table 2. Pesticide residues (ppb) on Chinese kale affected by pulsed light intensity (J/cm^2)

Pesticide residue (ppm)	Pulsed light intensity (J/cm^2)					
	0	1.2	3.6	6.0	8.4	10.8
Carbendazim	25.19±0.04^a	7.05±0.02^b	2.37±0.05^c	0.18±0.03^d	0^e	0^e
Abamectin	18.34±0.03^a	3.16±0.01^b	1.82±0.02^{bc}	0.09±0.01^c	0^d	0^d
Cypermethrin	9.51±0.06^a	1.39±0.04^b	0.21±0.03^c	0^d	0^d	0^d
chlorpyrifos ethyl	14.27±0.02^a	2.74±0.03^b	0.75±0.01^{bc}	0.13±0.01^c	0^d	0^d
Mancozeb	8.11±0.05^a	0.63±0.02^b	0.14±0.02^c	0^d	0^d	0^d

Numbers are the average of triplicate; characters in row followed by the same figure/s are not significant difference (α = P=0.05).

Table 3. Weight attrition (%) of Chinese kale affected by pulsed light intensity (J/cm^2)

Storage (days)	Pulsed light intensity (J/cm2)					
	0	1.2	3.6	6.0	8.4	10.8
2	2.18±0.05^a	1.05±0.04^b	0.73±0.05^{bc}	0.48±0.03^c	0.23±0.02^{cd}	0.09±0.03^d
4	3.94±0.04^a	2.39±0.07^b	1.54±0.02^{bc}	0.97±0.01^c	0.61±0.04^{cd}	0.24±0.01^d
6	6.42±0.03^a	3.75±0.02^b	2.09±0.04^{bc}	1.43±0.02^c	0.92±0.03^{cd}	0.51±0.00^d
8	8.37±0.06^a	4.99±0.03^b	3.12±0.03^{bc}	1.98±0.04^c	1.25±0.02^{cd}	0.96±0.04^d
10	10.54±0.02^a	6.27±0.04^b	4.53±0.01^{bc}	3.05±0.00^c	2.01±0.05^{cd}	1.33±0.02^d

Numbers are the average of triplicate; characters in row followed by the same figure/s are not significant difference (α = P=0.05).

withdrawal time from spraying to harvesting. Pre-harvest interval regulations normally set 7-14 days in Vietnam.[54] Pesticide residues on agricultural products was in alarming level.[55] Numerous toxic and illegal pesticide categories have been discovered in Vietnam local market.[56] Pesticide abuse in farming posed potential risks to human health, agro-ecosystem, wildlife habitat as well as environmental polution.[57-58]

Pesticide residues on the untreated samples of Chinese kale were quite high. Under pulsed light treatment, these pesticide residue gradually decreased towards pulsed light intensity. Pulsed light was identified as an appropriate alternative for the conventional pesticide residue removal method. Residues of carbendazim, abamectin, cypermethrin, chlorpyrifos ethyl, mancozeb were completely eliminated by pulsed light intensity over 8.4 J/cm^2 (Table 2). Chlorpyriphos ethyl, phosmet, azinphos-ethyl, pirimiphos-methyl, and atrazine were found to be 50% attrition by 0.7 J/cm^2 of pulsed light intensity.[60] The results suggested that pulsed light treatment could be used for other fresh vegetable to ensure food safety.

Weight attrition was positively correlated with moisture evaporation leading cell membrane damage and phenolic oxidation.[60] Weight attrition was accumulated slightly in the treated samples, meanwhile the steep increment was noticed in the untreated one. The lowest weight attrition was not significant difference on the sample treated by the pulsed light intensity 8.4 J/cm^2 or 10.8 J/cm^2 (see Table 3). Accelerated intensity of pulsed light induced to negative damage to quality criteria on salad and apple.[61-62] Ready-to-eat mushroom, cantaloupe, and mung bean sprout had no significant effect of weight attrition after pulsed light.[63] Several studies reported that respiration rate spinach and ready-to-eat cantaloupe increased after pulsed light treatment by influencing to the metabolic reaction of the cellular.[24,64] Lettuce and ready-to-eat mushroom had accelerated respiration speed by pulsed light.[27,65] Respiration speed of pulsed light-cured ready-to-eat avocado boosted during storage.[66] Ready-to-eat mango treated by pulsed light intensity 2.8 J/cm^2 had low weight attrition during 7 days of storage.[67]

Table 4. Textural hardness (N) of Chinese kale affected by pulsed light intensity (J/cm^2)

Storage (days)	Pulsed light intensity (J/cm^2)					
	0	1.2	3.6	6.0	8.4	10.8
0	5.84±0.01^a	5.75±0.02^a	5.79±0.00^a	5.82±0.03^a	5.85±0.01^a	5.80±0.02^a
2	4.08±0.02^c	4.12±0.03^c	4.37±0.02^{bc}	4.69±0.03^b	4.92±0.01^{ab}	5.19±0.02^a
4	3.95±0.03^c	4.01±0.01^c	4.12±0.00^{bc}	4.41±0.02^b	4.73±0.00^{ab}	5.01±0.03^a
6	3.48±0.01^c	3.51±0.02^c	3.85±0.03^{bc}	4.03±0.01^b	4.29±0.02^{ab}	4.62±0.01^a
8	3.00±0.02^c	3.03±0.00^c	3.29±0.01^{bc}	3.68±0.00^b	4.05±0.03^{ab}	4.30±0.00^a
10	2.77±0.00^c	2.81±0.03^c	3.05±0.02^{bc}	3.49±0.03^b	3.82±0.01^{ab}	4.04±0.02^a

Numbers are the average of triplicate; characters in row followed by the same figure/s are not significant difference (α = P=0.05).

Table 5. Dry matter (Brix) of Chinese kale affected by pulsed light intensity (J/cm^2)

Storage (days)	Pulsed light intensity (J/cm2)					
	0	1.2	3.6	6.0	8.4	10.8
0	12.04±0.03^a	12.11±0.00^a	12.03±0.02^a	12.01±0.00^a	12.07±0.01^a	12.08±0.00^a
2	11.20±0.00^b	11.23±0.02^b	11.51±0.01^{ab}	11.63±0.02^{ab}	11.89±0.03^a	11.97±0.01^a
4	11.03±0.02^b	11.05±0.03^b	11.19±0.03^{ab}	11.30±0.01^{ab}	11.59±0.02^a	11.62±0.00^a
6	10.49±0.03^b	10.53±0.01^b	10.82±0.00^{ab}	10.89±0.03^{ab}	11.18±0.00^a	11.25±0.03^a
8	10.18±0.01^b	10.24±0.02^b	10.52±0.03^{ab}	10.60±0.02^{ab}	10.98±0.01^a	11.04±0.02^a
10	9.79±0.02^b	9.88±0.00^b	10.15±0.01^{ab}	10.27±0.02^{ab}	10.59±0.03^a	10.67±0.00^a

Numbers are the average of triplicate; characters in row followed by the same figure/s are not significant difference (α = P=0.05).

Textural hardness is one of the most decisive indexes in vegetable during storage. Impact of pulsed light intensity to textural hardness of Chinese kale was shown in Table 4. Its' clearly realized that pulsed light treatment resulted to better retention of textural hardness during preservation. Meanwhile the textural hardness of the untreated sample went down steeply (5.84±0.01 N to 2.77±0.00 N) during 10 days of storage. There was not significant difference of textural hardness on Chinese kale pulsed light intensity 8.4 J/cm^2 and 10.8 J/cm^2. No significant degradation of textural hardness was noticed in fruits and vegetables treated by pulsed light.[25] Pulsed light stabilized textural hardness of ready-to-eat mango.[68] Pulsed light intensity 12 J/cm^2 maintained textural hardness of apple during 14 days of preservation at cool temperature.[69] Retention of textural hardness of raspberry treated with pulsed light was reported.[51] Strawberry treated by pulsed light maintained textural hardness when compared to untreated sample during 8 days of storage at 6°C due to cell wall reinforcement.[70] Decomposition of protopectin into water-soluble pectin is a major cause of leaft softerning.[71] Moreover, hemicellulose, and cellulose were strongly broken down during fruit preservation inducing to decreased textural hardness.[72] This softening is originated from the activity of cell wall-loosing enzymes such as polygalacturonase, pectin methylesterase, cellulase, β-galactosidase, and α—arabinofuranosidase.[73-75]

Dry matter (Brix) of Chinese kale treated by pulsed light intensity had higher retention compared to the untreated sample during 10 days of storage (Table 5). It's clearly found that pulsed light treatment at over 8.4 J/cm^2 effectively maintained dry matter. It could be explained by low respiration rate on Chinese kale under pulsed light radiation. Pulsed light until 53.3 J/g did not signficantly affect dry matter in apple juice.[76] There was not significant difference on dry matter of ready-to-eat cantaloupe at 4 ± 1°C treated by pulsed light.[64]

Table 6. Vitamin C (mg/100 g) of Chinese kale affected by pulsed light intensity (J/cm^2)

Storage (days)	Pulsed light intensity (J/cm^2)					
	0	1.2	3.6	6.0	8.4	10.8
0	22.44±0.01^a	22.47±0.03^a	22.46±0.00^a	22.51±0.02^a	22.43±0.03^a	22.48±0.02^a
2	21.08±0.02^b	21.13±0.01^b	21.58±0.02^{ab}	21.67±0.01^{ab}	21.96±0.00^a	22.03±0.00^a
4	20.36±0.00^b	20.49±0.02^b	20.95±0.01^{ab}	21.04±0.03^{ab}	21.48±0.01^a	21.56±0.03^a
6	19.97±0.01^b	20.04±0.00^b	20.47±0.03^{ab}	20.59±0.00^{ab}	20.91±0.02^a	21.04±0.01^a
8	19.18±0.02^b	19.27±0.01^b	19.83±0.00^{ab}	20.01±0.01^{ab}	20.49±0.03^a	20.58±0.00^a
10	18.87±0.00^b	19.01±0.03^b	19.28±0.02^{ab}	19.40±0.03^{ab}	19.97±0.01^a	20.05±0.03^a

Numbers are the average of triplicate; characters in row followed by the same figure/s are not significant difference (α = P=0.05).

Table 7. Total phenolic content (mg GAE/100 g) of Chinese kale affected by pulsed light intensity (J/cm^2)

Storage (days)	Pulsed light intensity (J/cm^2)					
	0	1.2	3.6	6.0	8.4	10.8
0	267.82±1.03^a	270.01±1.16^a	266.57±1.01^a	268.52±1.14^a	265.04±1.05^a	269.75±1.24^a
2	160.03±1.19^b	167.84±1.09^b	191.09±1.07^{ab}	202.27±1.01^{ab}	226.48±1.12^a	231.63±1.19^a
4	148.32±1.45^b	153.60±1.22^b	176.45±1.26^{ab}	183.52±1.15^{ab}	199.85±1.19^a	205.28±1.06^a
6	128.64±1.29^b	131.93±1.40^b	143.28±1.09^{ab}	150.10±1.23^{ab}	168.43±1.26^a	176.19±1.15^a
8	91.42±1.33^b	97.27±1.05^b	108.44±1.18^{ab}	112.05±1.30^{ab}	139.28±1.31^a	145.24±1.16^a
10	68.38±1.21^b	72.02±1.09^b	81.75±1.24^{ab}	89.43±1.08^{ab}	101.04±1.24^a	110.07±1.07^a

Numbers are the average of triplicate; characters in row followed by the same figure/s are not significant difference (α = P=0.05).

Ascorbic acid is one of the key organic acids in. Vitamin C in Chinse kale was effectively preserved during 10 days of storage by pulsed light intensity over 8.4 J/cm^2. High degradation of ascorbic acid was observed on the untreated sample (22.44±0.01 mg/100 g at beginning to 18.87±0.00 mg/100 g at the end of storage) (see Table 6). Pulsed light intensity 4.8 J/cm^2 effectively preserved the vitamin C content of ready-to-eat mushroom.[63] No significant degradation of ascorbic acid was noticed in fruits and vegetables treated by pulsed light.[25] Pulsed light 8 J/cm^2 had no significant effect on ascorbic acid content of ready-to-eat mango.[68] Pulsed light intensity at 11.7 J/cm^2 retained ascorbic acid of ready-to-eat cantaloupe[64].

Phenolics were key antioxidants strongly inhibited the overproduction of reactive oxygen species. In this demonstration, pulsed light handle positively restrainted the degradation of total phenolic content in the Chinese kale during storage. Meanwhile this content decreased steeply (267.82±1.03 to 68.38±1.21 mg GAE/100 g) in the untreated. Pulsed light intensity at 8.4 or 10.8 J/cm^2 could be applied to control phenolic decomposition (Table 7). Total phenolic content in green tomato was increased dramatically after pulsed light treatment.[76] No significant degradation of total phenolic content was noticed in fruits and vegetables treated by pulsed light.[25] The antioxidant activity slightly increased in in ready-to-eat cantaloupe treated by 7.8 J/cm^2 of pulsed light intensity.[64] Total phenolic contents in spinach and cantaloupe increased after pulsed light treatment.[24] Total phenolic content was not affected right after the treatment however it decreased significantly during storage.[51] Pulsed light intensity 2.8 J/cm^2 maintained the highest bioactive content in ready-to-eat mango during 7 days of storage.[67] Various literature confirmed that the organoleptic and nutritional characteristics of products treated by pulsed light were nearly intact.[24,50,65]

CONCLUSION

Microbial elimination and pesticide

removal on Chinese kale were very essential to ensure food safety. Pulsed light was examined Chinese kale leaf to verify its intensity on the efficacy of microbial and pesticide removal. This method involved in the application of swift light pulses released by Xenon flash lamp. Pulsed light intensity 8.4 J/cm^2 revealed significant attrition of pathogenic bacteria (*Escherichia coli*, *Staphylococcus aureus, Salmonella* load reduced to zero) and harmful pesticides (carbendazim, abamectin, cypermethrin, chlorpyrifos ethyl, mancozeb decomposed to zero) while controlling less weight attrition (2.01±0.05%), more sustain of textural hardness (3.82±0.01 N), dry matter (10.59±0.03 °Brix), vitamin C (19.97±0.01 mg/100 g) and total phenolic content (101.04±1.24 mg GAE/100 g) in Chinese kale during 10 days of storage. After PL-treatment, Chinese kale became more biological safety and better retention of quality attributes. Findings in this research opened a wide window in ensuring food safety and quality of other agricultural products.

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DATA AVAILABILITY

All datasets generated or analyzed during this study are included in the manuscript.

ETHICS STATEMENT

Not applicable.

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